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AGROTECHNOLOGY FOR FEED CULTIVATION AND CREATION OF HAYFIELDS AND PASTURES IN THE FOREST AND STEPPE ZONE OF NORTHERN KAZAKHSTAN

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SUMMARY

A high-quality feed base is a must to ensure the growing of numerous animals via selecting promising high-yielding crops that can provide livestock with feeds at the entire production stage. This study purposed to develop new technologies for reinstating a balanced use of pastures in Kazakhstan's steppe and forest-steppe zones. Several investigations succeeded in 2019–2022 at the Service-ZHARS Limited Liability Partnership (LLP) production fields of District Kyzylzhar, North Kazakhstan. Five chosen pasture combinations created multifactor pasture lands, as follows: common alfalfa + Festulolium; awnless brome + yellow sweet clover; common alfalfa + pasture ryegrass + Festulolium; white sweet clover + awnless brome + Timothy grass, and sainfoin + Festulolium + pasture ryegrass + Timothy grass. For haymaking and pasture chain construction, the following grass combinations selected comprised two-pasture grasses (previous years' brome and Timothy grass + common alfalfa + sainfoin) and seven hay grasses (vetch + oats, Sudan grass, sorghum-Sudan grass hybrid + sorghum, corn for silage, sorghum, peas + oats + barley + wheat, and peas). The use of drought-resistant legumes, cereals, and arable crops and their mixtures positively impacted intensifying the feed base and reducing the pasture areas' degradation. Thus, in the first experiment, the green mass collection was higher than 3.33 t ha^{-1}, while in the second one, it was below 4.75 t ha^{-1}, which fully bestowed the physiological needs of animals. The species diversity of pasture vegetation has improved because of beans' inclusion, possibly enhancing the protein ratio in green feed and hay as the main component of the farm animals' diet.

Keywords: Feed production, hay and pasture chain, mixed crops, nutritional value, rational use of pastures, yield of green mass

Key findings: Being drought-resistant and high-yielding, the selected promising cultivars of the various feed crops proved suitable for improving hayfields and pastures and creating a hay-pasture chain.

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INTRODUCTION

In agriculture, productive animal husbandry largely depends on the available high-protein and high-energy feeds. Vegetable protein is necessary for developing animal husbandry and many industries, and its deficiency is a challenge several countries face worldwide (de-Visser *et al*., 2014). The normalized feeding of farm animals hinges on the principles of balanced feeding following the animals' physiological needs (Konstantinova and Volodina, 2019; Nasiyev *et al*., 2021).

For solving the problems of feed production, preference should center on the annual and perennial crops with high protein. Feeds prepared from a multi-component mixture usually contain more proteins, carotenes, and energy and are acceptable for animals’ consumption. By eating such rich fodders, livestock contributes more to fully realize their genetic potential while reducing the cost of obtaining the concentrated feed (Savenkova, 2011). A crucial selection of promising grasses with high longevity, good adaptive ability, and highly productive herbage increase feed production with high protein value and energy. Therefore, preference should focus on the species and their cultivars that provide potential yield, environmental adaptability and sustainability, and resource-restoring functions (Kiryushin, 2019). At present, legumes with better nutritional value, harvest, and chemical composition have become increasingly widespread in feed production (Nogaev, 2021).

For getting a full-fledged grain feed, cultivating barley and pea mixtures comes as a suggestion since it exceeds pure barley crops in grain yield and increases the digestible protein content in the feed unit to 120–125 g, corresponding to the physiological norm of animals (Regional Council of the District Kyzylzhar, North Kazakhstan Region, 2022). Some other studies also showed that perennial legumes were superior in nitrogen-fixing ability to annual legumes with several cuttings per season, forming the non-deterministic nodules of regrowth cycles, which is vital for several subsequent rotations (Vance, 2001; Andrews and Andrews, 2017).

Legumes’ uniqueness is confirmed by their entrance into symbiosis with nodule bacteria, which fix atmospheric nitrogen (N_2), reducing it to amines (NH_4), and transport nitrogen to plants in the form of amides (Medicago, Trifolium, Lotus, Pisum) and ureides (Glycine, Phaseolus, Pisum) (Udvardi and Poole, 2013). In the agro-industrial complex of the Republic of Kazakhstan, the animal husbandry sector is the leading field. However, a shortage of feed with sufficient vegetable protein, carbohydrates, and other crucial elements of mineral nutrition has started. Thus, according to an analysis of the plant feeds produced in Northern Kazakhstan, there is a significant deficiency of essential proteins (30%–35%) and digestible carbohydrates (30%–40%) (Nokusheva, 2012).

The feed production development in Kazakhstan and several countries primarily consists of perennial crops, which provide a basis for food and environmental safety, agroecosystems sustainability, agricultural landscapes, and rational nature management (Nasiyev *et al*., 2022). The feed consumption rates planned for feeding farm animals in the diet mainly depend on the digestibility coefficients of the chemical components making up the feed composition. In addition, the diet also depends on the live weight of farm animals, their productivity, and their functional purpose. The multi-factor feed yield provides a 42% feeding ration for farm animals in North Kazakhstan (Malitskaya *et al.,* 2022).

Currently, feed production requires more efficient use of resources for producing feeds with lower costs. Achieving these goals entails a transfer of unproductive and heavily eroded lands from the arable category to improved hayfields and pastures to enhance the sowing of small-seeded crops, such as *Brassica napus* annua, *Barbarea vulgaris*, *Raphanus sativus* var. oleiferus, Sorghum × drummondii, Panicum, *Galega orientalis* (Janišová *et al*., 2016; Espinoza-Montez *et al*., 2018). Past studies stressed expanding the area of highly productive crops with the inclusion of *Medicago*, *Onobrychis*, *Melilotus*, and *Secale cereale* to improve the structure of feed with increased productivity and reduced costs (Renzi, 2009; Contreras-Paco *et al*., 2019).

In this regard, the studies related to developing resource-saving technologies for creating multicomponent pasture lands based on the efficient use of terrain and other climatic resources and the creation of a hay and pasture chain with annual and perennial feed crops for the production of full-fledged highly nutritious feed is of great scientific and practical interest in the steppe and forest-steppe zones of Northern Kazakhstan. The presented research sought to develop new technologies for restoring wise hay and pasture fields' use in Kazakhstan's steppe and forest-steppe zones.

MATERIALS AND METHODS

The pertinent study proceeded in 2019–2022 (January to December) at the Service-ZHARS Limited Liability Partnership (LLP) production fields of District Kyzylzhar, North Kazakhstan region (54°37′51″ N 69°09′19″ E). The total experimental and cultivated area was 3.5 ha. All the randomly sown experimental variants had four replications. The size of each sub-plot was 16 m wide and 24 m long. In parallel, experiments on the farm created multi-component pasture lands (for young animals of Holstein and Simmental breeds feed) and hay and pasture chain (for highly productive cows of Holstein and Simmental breeds for dairy production). Identifying the beneficial crops transpired to improve the feed base and create multi-component pasture lands (Table 1).

At the Service-ZHARS LLP, along with crop production, the sector of dairy animal husbandry continuously develops. Initiating experimental plots of multicomponent pasture lands for fattening young animals and a hay and pasture chain for highly productive cows supports continual feed supply. The field experiments' design shows in Tables 2 and 3.

Laboratory tests

Laboratory studies carried out before sowing helped determine the sowing qualities of the seed material of various crops, such as:

a. Seeds purity (two batches weighing 50 g each) isolation from the average samples of each plant for analysis for pure seeds (seeds of the main crop) and impurities (waste). The seeds' purity expression as a percentage of the seeds of the main crop and the total weight of the seeds;
b. The seed germination energy (the germinated seeds average for three (legumes) to seven (cereals) days of germination determined);
c. Germination test of the seeds (the germinated seeds percentage to the total number of seeds determined for 14 days); and
d. For 1000-seed weight in each crop (finding the total sum of two samples of 500 seeds of each crop weighed with an accuracy of 0.01 g).

Determination of the height of the snow cover

The snow cover height measurement used a portable snow measuring rail M-104 (M-104-I 1,800 mm long and M-104-P 1,300 mm long), with a division value of 10 mm. At the beginning of the route (the first measurement point), a portable snow measuring rail appraised the height of the snow cover. Next, measuring the altitude of the snow cover proceeded along the route every 20 m in the field and every 10 m in the forest.

Table 1. Productive crops for creating multicomponent pasture lands.

Crops	Environmental features	Feed value, feed units/kg of feed	Use
White sweet clover (*Melilotus albus*, Fabaceae)	Undemanding to the soil, drought-resistant	0.18	Haymaking and pasture
Yellow sweet clover (*Melilotus officinalis*, Fabaceae)	Enriches the soil with nitrogen, drought-resistant	0.19	Haymaking and pasture
Awnless brome (*Bromopsis inermis*, Poaceae)	Winter-hardy, drought-resistant, well-consumed by farm animals, and long-term economic use	0.50	Haymaking and pasture
Common alfalfa (*Medicago satíva*, Fabaceae)	Cold-resistant, winter-hardy, drought-resistant, salt-resistant, high feed value	0.48	Haymaking and pasture
Perennial ryegrass (*Lolium perenne*, Poaceae)	Resistant to trampling, has good recovery ability after grazing	0.50	Haymaking and pasture
Timothy grass (*Phlum pratense*, Poaceae)	Winter-hardy, undemanding to the soil, drought-resistant	0.29	Haymaking and pasture
Festulolium (*Festulolium*, Poaceae)	Winter-hardy, resistant to trampling, drought-resistant	0.82	Haymaking and pasture
Sainfoin (*Onobrýchis viciifolia*, Fabaceae)	Winter-hardy and has a good recovery ability after grazing	0.54	Haymaking and pasture
Common vetch (*Vicia sativa*, Fabaceae)	Undemanding to soils, grows well in a mixture with cereals	0.46	Grass and grain flour, crushed grain, green mass, silage
Common oats (*Avena satíva*, Poaceae)	Cold-resistant, undemanding to the soil, grows well in a mixture with legumes	0.46	Whole grain, green feed, hay, haylage, oat straw
Sudan grass (*Sorghum* × drummondii, Poaceae)	Drought-resistant, not demanding on soils	0.52	Green feed, haylage, silage
Sorghum (*Sorghum*, Poaceae)	Drought-resistant, salt-resistant	0.12	Silage, hay, green feed
Sorghum-Sudan grass hybrid (*Sorghum* x drummondii, Poaceae)	Drought-resistant, salt-resistant	0.23	Green feed, hay, haylage, silage
Sugar corn (*Zea mays*, Poaceae)	Improves the physical and mechanical condition of the soil	0.21 (silage)	Silage
Green peas (*Pisum sativum*, Fabaceae)	Frost resistant, resistant to short-term drought	0.23	Green mass, straw, cleaning waste, and by-products of grain processing
Common barley (*Hordeum vulgare*, Poaceae)	Low-demanding for heat, drought-resistant, medium-demanding for soil fertility	0.34	Straw, chaff, grain feed, concentrated feed
Common wheat (*Triticum aestivum*, Poaceae)	Has a wide range of soil and climatic conditions	0.21 (straw)	Grain feed

Table 2. Design of field experiment one: creation of multicomponent pasture lands.

No.	Variants of pasture components
1	Common alfalfa + Festulolium
2	Awnless brome + yellow sweet clover
3	Common alfalfa + perennial ryegrass + Festulolium
4	White sweet clover + awnless brome + Timothy grass
5	Sainfoin +Festulolium + perennial ryegrass + Timothy grass

Table 3. Design of field experiment two: creation of a hay and pasture chain.

No.	Variants
1	Previous years' brome (B)
2	Timothy grass + common alfalfa + sainfoin
3	Vetch + oats
4	Sudan grass
5	Sorghum-Sudan grass hybrid
6	Corn for silage
7	Sorghum
8	Peas + oats + barley + wheat
9	Peas

Determination of the productive moisture reserve

For determining the productive moisture reserve, soil sampling continued manually using a special drill with a length of 1 m every 10 cm of soil depth. Each sample, taken separately in pre-weighed metal containers (weighing bottles), was rushed to the laboratory. The productive moisture reserve depth ranged from 0 to 100 cm, as determined by the thermostatic weighing method. The weighing bottles with samples underwent balancing on technical scales, with the soil dried to a constant mass in a thermostat at a temperature of 100 °C–105 °C, then re-weighed.

Soil sample analysis

The soil samples analysis occurred in the spring before sowing at the laboratory of Agro Marketing-Kazakhstan LLP (Agro-Test). The nitrates' determination ran by extracting nitrates from the soil with a solution of potassium chloride, followed by the reduction of nitrates to nitrites with hydrazine in the presence of copper as a catalyst and photometric determination of them in the form of a colored diazo-compound. The analysis result recorded the value of a single determination of nitrates. The verification of mobile sulfur began with the extraction of mobile sulfur from the soil with a solution of potassium chloride, precipitation of sulfates with barium chloride, and subsequent turbidimetric determination of them in the form of barium sulfate by the optical density of the suspension.

Diagnosis of mobile phosphorus and potassium compounds proceeded with the extraction of mobile phosphorus and potassium compounds from the soil with a solution of ammonium carbonate with a concentration of 10 g/dm having a soil-to-solution ratio of 1:20 and subsequently, phosphorus surfaced in the form of a blue phosphorus-molybdenum complex on a photoelectric colorimeter and potassium on a flame photometer. Distinguishing the organic matter started with the oxidation of organic matter with a solution of potassium bicarbonate in sulfuric acid and the subsequent distinction of trivalent chromium equivalent to the content of organic matter on a photoelectric colorimeter. Determination of the specific electrical conductivity, pH, and dense residue of the aqueous extract went on extracting water-soluble salts from the soil with distilled water at a soil-to-water ratio of 1:5, with the specific electrical conductivity of the aqueous extract determined using a conductometer and pH using a pH meter.

Chemical analytical studies of the soil

During chemical analytical studies, internal laboratory control applications pursued introducing previously analyzed samples and a state standard sample into each assessed batch of soil samples (with known values of the content of $N\text{-}NO_3$, P_2O_5, K_2O, and S). Northern Kazakhstan soils are mainly ordinary chernozems of medium strength, with medium humus capacity, and heavy and medium loamy soils. The soil of the experimental field contained a small amount of mobile phosphorus and a moderate amount of nitrogen. In the soil, the increased exchangeable potassium content positively impacted the growth and development of crops during the growing season.

Meteorological observations

The available moisture for crops is the key indicator of obtaining a stable supply of green and dry mass. In this regard, weather conditions annual monitoring continued during the study period. Since the region's climate is sharply continental, the available moisture conditions differed dramatically over the years. During the growing season, daily monitoring of the climatic conditions of the study area ensued, with the data recorded in the observation log and at the end of each month, also calculating the amount of precipitation.

Agrotechnical measures

Agrotechnical measures to create multi-component pasture lands and hay and pasture chain involving annual and perennial feed crops for the production of complete feed in the steppe and forest-steppe zone conditions of Northern Kazakhstan progressed according to the zonal agrotechnical recommendation of the region. Autumn plowing reached a 25–27 cm depth, followed by two-fold sod disking and harrowing. Spring harrowing occurred three times: on the third day of April, mulching took place; at the end of April was the second harrowing, and the third, at the beginning of the first day of May. Pre-sowing cultivation transpired on the first day of May, using a rotary cultivator to a depth of 6–8 cm. These agrotechnical measures made it possible to obtain the desirable physical and mechanical properties of the soil and to level plots' surface for sowing the various crops of the grass mixture.

Biometrical studies

The botanical composition of the herbage determination ran the analysis for biological elements after cutting in 1 m^2 with each repetition of variants. The weighed samples helped determine the share participation of fractions. The dynamics of linear growth estimation had plants measured at each repetition of variants in 1 m^2 as the phenological phases of the herbage elements began. The dynamics of plant height establishment had 10 plants of each component measured diagonally on the pasture plot.

Determining the density of herbage and the degree of their sprout formation went on by counting vegetating plants and their organs in 1 m^2 of each repetition of variants. Crop yield accounting proceeded by the cutting method (cutting grasses from four sites of each variant of the experiment by 2.5 m^2 to a height of 5–6 cm, followed by weighing and recalculation per ha). The harvested arable crops' accounting employed a continuous method (cutting the grasses and weighing the mass from each accounting plot in the field immediately after harvesting). Considering the silage crops yield, crushed samples weighing 1 kg determined the content of air-dry and purely dry matter in percentage. Annual and perennial grass cutting and calculating used a continuous method, followed by a simultaneous weighing of green mass and dried hay.

Data analysis

After re-weighing, calculations of the productive moisture reserve ran according to the formula:

$$W = 0.1\ qh\ (u\text{-}k),$$

Where W is the reserve of productive moisture (mm); q is the mass of 1 cm^3 of soil (g); h is the thickness of the soil layer, which determines the reserve of productive moisture (cm); u is the humidity of absolutely dry soil (%); k is the humidity of permanent wilting (%); and 0.1 is the coefficient of conversion of the reserve of productive moisture (in mm) of the water layer.

The mass fraction of organic matter calculation as a percentage used the formula:

$$X = (100 - m),$$

Where:
m is the mass fraction of ash content (%).
The yield of green mass determination followed the formula:

$$X = \frac{A \cdot a}{(a - в)},$$

Where:
X is the given crop (kg); A is the actual crop obtained from the plot on which the sampling was made; a is the area (m^2) of the normal plot; and b is the sampling area (m^2).

The harvest of green mass resulted in 16% of the standard moisture content of hay:

$$X = \frac{У\,(100 - B)}{84},$$

Where:
X is the hay harvest at 16% humidity (c/ha); Y is the harvest of green mass (c/ha); B is the humidity of green mass during harvesting (%); 84 is the conversion factor for 16% humidity.

RESULTS

Sowing qualities of seeds

According to the variants, the purity of the seed material was high (92.3%–98.1%). Legumes showed low germination energy (31.4%). In other variants, the germination energy and laboratory germination, as well as, the 1000-seed weight, were within the normal range. Continuous provision of green feed is possible by sowing in compliance with agricultural practices for each crop. Phenological observations showed that the onset of the main phases of development occurred within the normal range.

Soil conditions

Soil analysis provided that accretion of productive moisture, agrophysical indicators, and chemical composition allowed crop plants to realize their genetic production potential. In the experimental plots, taking soil samples before sowing determined the humus content and prime nutrients (Table 4). According to the main nutrient content, the humus and nitrogen content in the soils of the surveyed fields indicated an average level. However, in the ground of the experimental site, the mobile phosphorus content was scarce (19.8 mg kg^{-1}), whereas the exchangeable potassium content was high (346.0 mg kg^{-1}). The soil used for the experimental plots had a slightly alkaline soil reaction (pH = 7.5).

The recorded data revealed a slight deviation from the chemical composition of the soil of the experimental site, and the average indicators have a sufficient amount of necessary nutrients and fertility levels to realize the potential of the cultivated plants selected for the experiment in the study area. Thus, the surveyed fields with a high level of agricultural technology will provide higher crop yields with better quality. In the fields, the relationship between the accumulation of productive soil moisture and snow cover is

Table 4. Agrochemical characteristics of the soil.

Soil horizon (cm)	Humus (%)	pH (H_2O)	Common (%) Nitrogen	Phosphorus	Potassium	Mobile (mg kg^{-1}) $N\text{-}NO_3$	P_2O_5	K_2O
0-20	5.7	7.0	0.31	0.18	2.51	15.8	29	415
20-40	5.1	7.3	0.27	0.19	2.12	17.8	28	380
40-60	4.3	7.6	0.21	0.10	1.96	15.2	18	325
60-80	3.7	7.7	0.18	0.09	1.87	12.6	13	310
80-100	3.6	7.8	0.18	0.07	1.85	11.9	11	300

Table 5. Conditions of moisture availability in the region under study.

Years of the study	Monitoring of snow cover height (cm)	Content of productive moisture in the soil (mm)	Amount of precipitation during the growing season (mm) May	June	July	August
2019	18	142	21	52	44	34
2020	15	148	37	25	27	30
2021	10	90	7	17	57	35
2022	20	145	25	38	56	23
Average by year	15.7	128.7	22.5	33	46	30.5

available in Table 5. The minimum productive moisture accumulation was notable in crop seasons with low indicators, increasing the germination period. A lengthy period of the main phenophase did not allow optimal yields in the variants of the experiment with the observance of agricultural technology.

Growth, development, and productivity

Multi-component pasture lands for fattening young animals

The yield formation depends on the plants' density and height. According to the first indicator, the yield is predictable: the number of plant seedlings is the basis of the projective cover of the herbage. The plants' heights helped predict their growth and development. According to a combination of these indicators, it becomes possible to calculate the biological yield (Table 6). The plant density and height variables were within the physiological norm. In the pasture, the grass and legume mixtures positively affected the species composition of the herbage. Thus, there was no loss in herbage components during the observation period.

On green mass yield, the cuttings ensued in the ear emergence/flowering phase. The hay yield determination also followed the cutting method (Table 7). The studies revealed that the highest yield resulted in the pasture combinations of common alfalfa + Festulolium at 5.94 t ha^{-1} of green mass with hay output of 1.99 t ha^{-1}. However, the lowest average yield recorded appeared in the variant of white sweet clover + brome + Timothy grass, 3.33 and 1.17 t ha^{-1}, respectively, and this reduction in harvest might be due to the poor survival of Timothy grass.

In terms of the nutritional quality of feed, alfalfa, as a perennial legume crop, provided the highest yield of feed units (0.74–0.96) and crude protein (218.8–230.8), with the maximum metabolizable energy (11.9–14.5). Awnless brome in mixed sowing with sweet clover followed, yielding 0.79 feed units, 237.2 crude proteins, and 11.7 MJ of metabolizable energy. Optimal use of selected drought-resistant grass and legume mixtures enunciated a positive impact on the green mass yield and the yield of feed units (Table 8). In recording the data on feed units and digestible protein, the best indicators occurred in variants one and two, represented by two-component mixtures. The grass mixtures also provided a larger average yield.

Table 6. Plants' density and height during the study period.

No.	Variants of pasture components	Herbage density (pcs/m^2)				Height of the herbage (cm)			
		2019	2020	2021	2022	2019	2020	2021	2022
1	Common alfalfa	122	121	118	97	59.3	58.9	56.5	41.3
	Festulolium	185	188	177	195	39.6	32.5	35.9	31.8
2	Awnless brome	122	118	126	120	69.9	68.6	65.5	52.0
	Yellow sweet clover	178	175	165	177	55.9	62.5	57.7	59.5
3	Common alfalfa	112	115	96	109	68.2	69.5	63.1	36.3
	Perennial ryegrass	78	82	85	65	42.8	46.6	42.2	45.5
	Festulolium	145	142	118	138	43.7	42.5	37.5	42.2
4	White sweet clover	142	141	98	147	48.5	48.8	51.2	47.4
	Awnless brome	112	112	107	65	59.5	62.2	57.5	59.6
	Timothy grass	26	25	22	24	36.9	37.5	35.9	39.5
5	Sainfoin	78	75	73	48	62.2	72.9	66.3	30.3
	Festulolium	142	135	89	144	48.6	46.8	45.4	45.9
	Perennial ryegrass	69	62	59	54	43.7	46.8	44.6	48.2
	Timothy grass	55	52	45	47	35.9	39.7	36.9	37.7

Table 7. Yield and nutritional value of pasture grass mixtures.

No.	Variants of pasture components	Yield (t ha^{-1})									
		2019		2020		2021		2021		On average for 2019–2022	
		green mass	hay	green mass	hay	green mass	hay	green mass	hay	green mass	Hay
1	Common alfalfa + Festulolium	6.86	2.22	5.99	2.12	3.95	1.32	6.95	2.28	5.94	1.99
2	Awnless brome + yellow sweet clover	4.58	1.65	4.42	1.59	4.07	1.39	4.34	1.52	4.35	1.54
3	Common alfalfa + perennial ryegrass + Festulolium	3.66	1.28	5.23	1.59	3.54	1.18	5.43	1.68	4.47	1.43
4	White sweet clover + awnless brome + Timothy grass	0.37	0.19	0.26	0.12	0.85	0.05	0.85	0.41	0.33	0.17
5	Sainfoin + Festulolium + perennial ryegrass + Timothy grass	0.99	0.36	0.88	0.67	0.55	0.18	0.55	0.18	0.34	0.56
LSD_{095} (c ha^{-1})		0.22	0.09	0.48	0.48	0.22	0.12	0.22	0.12	0.12	0.12

Hay and pasture chain for highly productive cows

The green mass yield determination accounted for the plants' density and height (Table 9). The studied indicators were also within the normal range. However, in the unfavorable humidification condition of 2021, the plant height was slightly lower than the average long-term. It was due to the variation in the duration of the tillering and branching phases due to uneven precipitation during the growing season. Humidification conditions also affected the yield of green mass (Table 10). In the year 2021 (dry), there was a decrease in the yield index in all variants of the experiment.

The results further showed a higher yield of green mass in the variants of arable crops and cereals of high-stemmed crops. Thus, in 2021–2022, their outputs did not fall below 11.07 t ha^{-1} (average 12.27 t ha^{-1}) under the moisture deficiency conditions during 2021 and were the highest in humidification favorable conditions during 2022, amounting to 16.0 t ha^{-1} (average 14.15 t ha^{-1}). The nutritional value of the green mass obtained

Table 8. Feed nutritional value.

No.	Variants of crops and grass mixtures	Average hay yield (t ha^{-1})	Nutritional value of feed					
			feed units (t ha^{-1})	crude protein (kg ha^{-1})	incl. digestible protein (kg ha^{-1})	feed protein unit (t ha^{-1})	Metabolizable energy of hay (MJ/t)	
							Cattle	Goats and sheep
1	Common alfalfa + Festulolium	1.99	0.96	230.84	151.24	0.595	13.512	14.467
2	Awnless brome + yellow sweet clover	1.54	0.79	237.16	183.26	0.514	10.934	11.704
3	Common alfalfa + perennial ryegrass + Festulolium	1.43	0.736	218.79	153.10	0.478	11.011	11.869
4	White sweet clover + awnless brome + Timothy grass	1.17	0.562	106.47	59.67	0.335	7.547	7.900
5	Sainfoin + Festulolium + perennial ryegrass + Timothy grass	1.56	0.78	140.4	92.04	0.461	10.265	10.983
LSD_{095}		0.015	0.012	4.8	1.95	0.014	0.13	0.17

Table 9. Height and density of herbage components (2019–2022).

No.	Variants of pasture components	Herbage density (pcs/m^2)				Height of the herbage (cm)			
		2019	2020	2021	2022	2019	2020	2021	2022
1	Previous years' brome	198	196	150	189	82.8	85.5	73.3	80.2
	Timothy grass	32	35	36	34	37.9	38.5	36.9	39.59
2	Common alfalfa	128	126	119	117	57.3	57.9	53.5	51.3
	Sainfoin	75	74	73	68	61.5	71.9	64.6	31.9
3	Vetch	151	142	148	145	66.9	62.8	64.8	52.3
	Oats	148	145	142	141	62.2	59.5	55.7	55.5
4	Sudan grass	136	132	70	139	112.8	98.3	75.7	115.6
5	Sorghum-Sudan grass hybrid	48	45	38	46	86.4	78.9	64.2	85.2
6	Corn for silage	9	8	6	8	142.7	136.8	140.6	129.1
7	Sorghum	35	36	30	32	81.9	75.7	66.4	80.2
8	Peas	55	58	59	62	62.7	59.9	60.3	50.5
	Oats	72	68	62	78	58.2	58.5	55.2	57.5
	Barley	85	86	82	87	62.8	62.2	59.9	51.7
	Wheat	88	85	83	85	62.4	62.8	59.5	57.5
9	Peas	155	157	150	152	45.7	42.2	30.6	45.2

Table 10. Yield of crops and their mixtures of the hay and pasture chain.

No.	Crops	Green mass (t ha^{-1})				Average yield (t ha^{-1})
		2019	2020	2021	2022	
1	Previous years' brome (b)	4.58	4.62	4.57	5.23	4.75
2	Timothy grass + common alfalfa + sainfoin	5.89	5.93	5.74	6.83	6.10
3	Vetch + oats	5.96	6.24	5.82	9.05	6.77
4	Sudan grass	7.88	7.85	7.54	9.73	8.25
5	Sorghum-Sudan grass hybrid	11.57	11.42	11.23	12.05	11.57
6	Corn	14.89	15.28	14.51	16.00	15.17
7	Sorghum	11.35	11.58	11.07	11.74	11.44
8	Peas + oats + barley + wheat	8.28	7.89	7.86	11.20	8.81
9	Peas	5.16	5.25	4.97	14.40	7.45
LSD_{095}		0.159	0.172	0.328	0.375	-

Table 11. Average yield and nutritional value of the green mass of crops.

No.	Variants of crops and grass mixtures	Average yield (t ha^{-1})	Nutritional value of feed					
			feed units (t ha^{-1})	crude protein (kg ha^{-1})	incl. digestible protein (kg ha^{-1})	feed protein unit (t ha^{-1})	Metabolizable energy of hay (MJ/t)	
							Cattle	Goats and sheep
1	Previous years' brome	4.75	1.188	204.25	123.5	0.696	14.915	16.103
2	Timothy grass + common alfalfa + sainfoin	6.10	1.159	238.8	158.6	0.70	12.505	13.481
3	Vetch + oats	6.77	1.557	230.18	162.48	0.894	16.587	9.952
4	Sudan grass	8.25	1.650	231.0	148.5	0.941	17.820	18.150
5	Sorghum-Sudan grass hybrid	11.57	2.314	231.4	161.98	1.273	24.528	25.224
6	Corn for silage	15.17	3.034	379.25	212.38	1.707	34.891	38.077
7	Sorghum	11.44	2.288	228.8	160.16	1.259	24.253	24.939
8	Peas + oats + barley + wheat	8.81	1.850	334.78	266.80	1.093	18.855	18.413
9	Peas	7.45	1.714	275.65	193.70	0.995	18.625	19.519
LSD_{095}		0.015	0.012	4.8	1.95	0.014	0.13	0.17

used a hay and pasture chain, as reflected in Table 11. Moisture conditions also affected the nutritional value. However, considering the average figures for the entire observation period, it is noteworthy that the feed units and digestible protein increased two times or even more.

DISCUSSION

In the Northern region of Kazakhstan, the conservation, expanded restoration, and increased productivity of natural feed lands are vital in creating a solid feed base for livestock (Maslikhat of Akmola region, 2012). Feeds from multi-component pastures and a hay and pasture chain contributed to strengthening the feed base of the farm, ensuring complete and good quality feeding of farm animals.

In leguminous crops, unfavorable weather conditions at certain vegetation stages affected the yield and showed instability (Redden *et al*., 2014; Bhandari *et al*., 2016; Gataulina *et al*., 2020). The selection of high-yielding drought-resistant crops and their mixtures transpired in such a way as to minimize the influence of environmental factors, in particular, the lack of moisture on the productivity of feed crops. These crops are not demanding to the conditions of moistening during germination, and the plants' potential boosts the formation of an embryonic root even with minimum moisture content in the soil.

High temperature and water deficit stress conditions can cause complex and irreversible variations in the growth and development of crop plants and the formation of productivity elements (Devasirvatham *et al*., 2015; Cattelan and Dall'Agnol, 2018; Khalizova and Zykov, 2019). Such stressful conditions naturally happen more often due to climate change on a large scale. These were the causes of instability and variability in the yield of legumes, even when growing these crops in the most favorable climatic regions of the USA, Brazil, and Argentina, which are major suppliers to the global market. The amount of precipitation is also a determining factor in the formation of yield (de-Visser *et al*., 2014; Khokonova and Adzhieva, 2019; Hakala *et al*., 2020), and the presented results also fully correspond to the above statements.

Therefore, in the crop seasons with satisfactory moisture and precipitation during the growing season, superior indicators of yield and collection of essential nutrients were notable, allowing to obtain on average 1.86 t ha^{-1} of feed units, 261.57 kg ha^{-1} of crude protein, and 176.46 kg ha^{-1} of digestible protein.

Moderate summer precipitation, especially during critical periods of plant development (June and July) (Long and Ketterings, 2016), and a temperature regime above average contributed to the harvest of feed raw materials in the optimal period (June and July) (Corbeels *et al*., 2016; Pavlenko *et al*., 2018). The relevant study authenticated that the productivity and collection of feed units directly depend on soil moisture reserves, and future moisture availability. In 2021, the minimum precipitation during the study years affected the crops' yield. In 2021, the output was 15% lower than the values obtained in the other years of the study period.

The feed crops' maturity depends on the ratio of leaves and stems; thus, when their ratios vary, there will be variations and instability in the feed crop yield and nutritional values (Grev *et al*., 2020). Feed harvesting mainly depends on the external parameters of crop development (Ta *et al*., 2020). In the flowering phase of feed crops, the first cutting as a relative indicator best defines as follows: it is better to cut the green mass at the beginning of flowering based on the nutritional value, fermentation characteristics, and digestibility of feed in the rumen of animals (Guo *et al*., 2019; Claessens *et al*., 2021).

The meaningful results also confirm the above conclusions of the past studies, namely, cutting plants in optimal time contributed to a higher collection of nutrients. Similarly, the vegetative mass during the cutting period had a key influence on the yield index. Thus, the maximum amount of nutrients, vitamins, and protein was acquired in the vegetative mass of cereal grasses during the tillering phase and in legumes during the branching period. The further development of plants decreases the nutrient content in feed crops as the number of leaves declines and the stems increase. However, cutting grasses in the early period of their development is economically unprofitable since, during that period, the grasses provide a minimal yield of green mass. In the vegetative accumulation, the nutrient content determination showed a balance of the green feed with protein if harvesting feed crop mixtures happens during the earring in cereals and flowering in legumes.

The developed schemes of multicomponent pastures and a hay and pasture chain have been tested successfully in the simple farm. The introduction of legumes and cereals into the experiments increases the yield per unit area, improves the structure of pasture vegetation, increases the collection of the protein component, and prevents soil degradation.

CONCLUSIONS

In soil fertility studies, limited phosphorus content exists, which is typical for the soils of this region. In general, the primary nutrient contents (sodium, phosphorus, potassium [NPK]), humus, and acidity index were sufficient for the yield formation of these crops. The selected drought-resistant and high-yielding cultivars of feed crops proved suitable for improving hayfields and pastures and creating a hay-pasture chain. The chosen experimental design reduced the protein deficiency by including a legume component, ensuring high yields even in adverse weather conditions in Northern Kazakhstan. In all crops, except legumes, the purity was high, and the germination energy, laboratory germination, and the 1000-seed weight were within the normal range. According to the study years, there was a nonsignificant difference in plant development; the plant height and density indicators were also within the normal range. Overall, the highest yield resulted in the combination of common alfalfa + Festulolium at 5.94 t ha^{-1} of green mass with hay output of 1.99 t ha^{-1}. However, the lowest average yield occurred in the white sweet clover + brome + Timothy grass combination, yielding 3.33 and 1.17 t ha^{-1}, respectively. The presented study on the development of multicomponent pasture lands and a hay and pasture chain in the forest-steppe zone of Northern Kazakhstan allowed to obtain, on average, 1.86 t ha^{-1} of feed units, 261.57 kg ha^{-1} of crude protein, and 176.46 kg ha^{-1} of digestible protein. The study limitations include variants with the inclusion of Timothy grass in the mixture, as these variants have low productivity of both green and dry mass due to the poor survival of this crop.

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