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Productivity, Quality, And Amino Acid Composition Of Sudan Grass And Sunflower Mixtures Grown With Soybean And/Or Spring Vetch For Haylage-Silage Use.

Vasin VG, Tcybulskii AV, Vasin AV, Kiseleva LV, Kozhevnikova OP, Saniev RN, and Adamov AA.

Dept of plant breeding and agriculture department, FSBEIHE Samara State Agricultural Academy, 446442, Russia, Samara, Ust-Kinelskii, Uchebnaya st. 2

ABSTRACT

The creation of mixed species enables farmers to significantly increase the fodder value of the crops when balanced with digestible protein. This study aimed to increase the productivity and quality of mixed-species stands of Sudan grass and sunflower in systems of haylage and silage using crops mixed with spring vetch and soybean at different levels of mineral fertilization. The study objectives included the assessment of advantages, yield capacity, chemical composition, and fodder value of Sudan grass and sunflower in both pure form and when mixed with legumes at harvest for haylage and silage. The findings were based on various levels of mineral nutrition. Mixed-species crops typically form thick haulm stands with large, tiered assimilation surfaces that generate high yields of phytomass. The use of mixed crops of traditional cultures with legumes will significantly enrich the phytomass of species mixtures with respect to protein, fat, and ash elements. Complex cenoses planted for production of digestible protein were significantly more productive than Sudan grass and sunflower crops alone; they provided a greater yield of fodder units and a good nutritional balance with added protein. During the present study, the influence of legume components on the composition of amino acids in haylage and silage was analyzed for treatments with and without fertilizers. The use of fertilizers generally increased the amino acids content of crops. Among the species mixtures of silage treatments studied here, on the basis of the amino acid composition of the phytomass, the sunflower-soybean mixture provided relatively high protein content and the most nutrients.

Keywords: Sudan grass, sunflower, soybean, spring vetch, haylage, silage, yielding capacity, chemical composition, fodder advantages, amino acids.

Corresponding author

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INTRODUCTION

Successful management of animal husbandry is impossible without the provisioning of livestock with the necessary amount of feed balanced by digestible proteins. In this connection, studies aimed at developing modern techniques for the formation of highly productive mixed-species agrophytocenoses of fodder crops for haylage-silage use are of particular relevance. These provide stable yields of phytomass balanced by digestible protein and other physiologically active substances within zootechnical norms.

The creation of agrophytocenoses enables ranchers to significantly increase the fodder value of the fodder mass and to balance it with digestible protein within 105–132 g per 1 fodder unit.

Freshly-mown and cured plants are silaging and haying to obtain preserved feed that does not differ in nutritional value from the initial material and does not lose its feed quality under long-term storage [13].

Currently, agricultural crops do not typically optimize forage species composition. In addition, climatic change affects the need to use drought-resistant crops for fodder production. Many scientists believe that the most accessible and promising multi-purpose planting systems include Sudan grass [1, 11, 14].

However, the content of economically valuable elements in Sudan grass depends greatly on the timing and phase of mowing as well as on environmental factors. For example, the greatest amount of digestible protein and amino acids is present during the heading phase [2, 15, 16, 17].

In contrast to perennial grasses, annual Sudan-bean mixtures used for haylage are harvested at a later term, such as during the formation of beans at their stage of milky wax ripeness. The nutrient content of the dry matter is less decreases with the age of plants [3, 18].

When preparing forage for livestock, many farmers and farm households cultivate silage varieties of sunflower [4, 5]. The advantages of this type of culture are well known because the photomass of single-species sunflower crops provided poorly balanced amounts of digestible protein. To solve this problem under conditions of production, mixed crops of sunflower with leguminous plants are often planted [1, 6, 19, 20].

The present study aimed to increase the productivity and quality of plants composed of a mixture of Sudan grass and sunflower in haylage and silage systems including crops mixed with spring vetch and soybean that were added to provide preferred levels of mineral fertilization to livestock [12]. The study objectives included an assessment of the yield capacity, chemical composition, and fodder advantages of Sudan grass and sunflower in pure form and when these crops were mixed with legumes during harvesting for haylage and silage, with various backgrounds of mineral fertilization. The amino acid composition in Sudan grass and sunflower mixtures was analyzed when these plants were grown with legumes during harvesting for silage.

MATERIALS AND METHODS

This research was conducted in Samara State Agricultural Academy on the experimental field of the Plant Cultivation and Agriculture Department. The soil of the plot was a typical heavy loam chernozem with residual-carbonate and medium-humic content. Annual grasses had previously been grown in the test plot. Agricultural techniques was common in this area.

In the period of 2011–2014, field experiments were conducted with the following 11 treatments (seeding rates are presented in millions of germinated seeds per ha): 1) Sudan grass (3.0); 2) Sudan grass + Vetch (2.0 + 0.8); 3) Sudan grass + Soybean (2.0 + 0.4); 4) Sudan grass + Vetch + Sunflower (1.5 + 0.6 + 0.1); 5) Sudan grass + Soybean + Sunflower (1,5 + 0,3 + 0,1); 6) Sunflower + Vetch (0.12 + 1.2); 7) Sunflower + Soybean (0.12 + 0.4); 8) Sunflower + Sudan grass (0.15 + 2.0); and 9) Sunflower (0.2). Three levels of mineral fertilization were used: 1) the control treatment (without fertilizers); 2) conditional Background 1 (use of a dose of fertilizer for the planned yield of 4.5–5.0 thousand fodder units (Ammophos 2.5 q/ha)) and 3) conditionally Background 2 (for planned yield of 6.0–6.5 thousand fodder units (Ammophos 3.8 q/ha)). Each treatment was done in three replications.

Meteorological conditions featured contrasting conditions during the years of research: for example, higher than average temperatures occurred from May to August in 2012 and 2013, but in 2011 and 2014 was much less heat observed for the same period.

In the hot days of July 2012 and 2013, the temperature reached an average of 24–25°C when precipitation totaled only 31.6 and 37.6 mm in each July, respectively, creating droughty conditions. In contrast, abundant rain fell at the beginning of the growing season in both 2011 and 2014; for example, 100 mm of precipitation fell in June 2014.

RESULTS

Phenological observations during the study revealed that sunflower and Sudan grass sprouts appeared on days 13–15 after sowing and those of legumes on days 8–12. No differences in the timing of emergence of seedlings were observed between plantings of single-species and mixed crops of Sudan grass and sunflower. Because the plants grew in mixed-species crops, a slight delay occurred in the development phases later on. This delay of the development was easier to observe on the main component in the second half of the growing season.

The degree of mutual suppression of plants grown in mixed agrocenoses can be determined by their stand density and survival at harvest. Therefore, when assessing the completeness of sprouting, no significant difference was observed in single-species crops of Sudan grass and mixtures with it (72.6%–75.6%). Meanwhile, sunflower showed some suppression in mixtures where the completeness of sprouting was 2.3%–11.3% lower than that in the mono-planting.

During vegetative growth, some plants inevitably die; however, high percentages of plants in our experiments survived until harvest. Sudan grass had the highest survival rate when planted with sunflower. On average, over this four-year study, this indicator ranged from 90.9% for the control and before the study to 94.4% for the Background 2 treatment. In the pure stand of sunflower, the survival rate at harvest approached 99%, while in mixed-species planting it was within 90.2%–98.8%. Notably, the mixed-species plots had survival rates that were higher than that in the two-component ones.

The germination and survival rates of plants were higher when fertilizer was applied.

Along with the density of the haulm stand, the parameter that determined the accumulation of vegetative phytomass was the linear growth of plants and the height of the stems. Sudan grass and sunflower grew taller in single-species plantings than in mixtures. However, an exception was a mixture of Sudan grass and vetch, where an inverse relationship was observed; that is, Sudan grass here grew taller when grown with vetch than in the single-species plot of Sudan grass.

By harvest time, Sudan grass plants grew to heights of 86.1–119.5 cm, depending on the level of mineral fertilization. In three-component mixture treatments, layering was well-developed; therefore, vetch and soybean plants comprised the lower tier (41.0–50.4 cm), sunflower comprised the middle tier (89.0–99.8 cm), and Sudan grass formed the upper tier (110.1–119.5 cm).

During this study, increased doses of mineral fertilizers resulted in a significant increase in the aboveground phytomass of the cultures and mixtures under study.

Measures of yield served as the most important indicator of the agricultural value of plants. This crucial indicator was affected by all of the factors that develop during the period of plant growth and development.

As expected, weather influenced the results of the study. Under the field conditions experienced during the study, all treatments were more productive by 15%–47% in 2012–2013 than in 2011 and 2014.

The present four-year study revealed that in a haylage assessments, mixtures of Sudan grass with sunflower and vetch or soybean competed well in terms of yield capacity, depending on the weather

conditions that developed during the observations. Therefore, in 2012 and 2013, the yield was higher in the treatment mixture with soybean, and in 2011 and 2014 it was higher in the mixture with vetch (Table 1).

The mixed-species crops had dense haulm stands and large, tiered assimilation surfaces that generated high yields of green phytomass. When harvesting for haylage (in the phase of Sudan grass ear formation), on average for the 4 years of research, the greatest yield was provided by the mixture of Sudan grass with vetch and sunflower, which created from 25.5 t/ha without fertilizer application to 30.2–32.3 with the two background treatments used here.

Table 1: Yield capacity of Sudan grass mixtures when mown for haylage (t/ha)

Treatment		Years				Average
		2011	2012	2013	2014	
Control	Sudan grass	19.1	20.2	22.4	17.1	19.7
	Sudan grass + Vetch	17.3	25.1	27.6	16.3	21.6
	Sudan grass + Soybean	14.5	24.2	26.8	10.5	19.0
	Sudan grass + Vetch + Sunflower	24.1	27.9	29.7	20.1	25.5
	Sudan grass + Soybean + Sunflower	14.7	31.0	32.4	14.1	23.1
Background 1	Sudan grass	27.7	22.4	26.7	26.7	25.9
	Sudan grass + Vetch	19.2	27.3	29.4	16.2	23.0
	Sudan grass + Soybean	18.4	25.7	27.2	17.4	22.2
	Sudan grass + Vetch + Sunflower	26.3	34.3	36.9	23.3	30.2
	Sudan grass + Soybean + Sunflower	17.1	37.4	39.4	14.1	27.0
Background 2	Sudan grass	27.3	26.4	28.6	23.3	26.4
	Sudan grass + Vetch	22.4	29.1	31.4	20.4	25.8
	Sudan grass + Soybean	18.1	27.7	27.9	15.1	24.7
	Sudan grass + Vetch + Sunflower	28.8	36.3	38.4	25.8	32.3
	Sudan grass + Soybean + Sunflower	20.1	42.7	44.9	16.1	31.0
	LSD_{05}. tot.	0.16	0.11	0.13	0.18	

The three-component mixture with soybean and sunflower was somewhat inferior and generated 23.1–31.0 t/ha of green phytomass.

Productivity of two-component mixtures of Sudan grass with vetch or soybean was 16%–37% less and was even lower than the indices of single-species crops of Sudan grass that generated 19.7–26.4 t/ha of phytomass.

When studying the productivity of mixtures for use in silage, the phase of sunflower blossoming was mowed. Studies revealed that monocenoses of sunflower provide a yield of 45.0–55.2 t/ha of green phytomass, depending on the level of mineral fertilization (Table 2).

In pure crops of Sudan grass, phytomass content was significantly lower, in the range of 5.73%–8.03%. In mixed crops of Sudan grass with legumes, the protein content in the crop increased significantly when compared with Sudan grass alone.

Therefore, when mowing for haylage, even a small percentage of vetch plants in the cenosis with Sudan grass and sunflower increased the amount of protein in the total phytomass by 6.77%–10.85%.

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Table 2: Yield capacity of mixtures when mown for silage (t/ha)

Treatment		Years				Average
		2011	2012	2013	2014	
Control	Sudan grass	19.6	22.3	24.6	18.6	21.3
	Sudan grass + Vetch	20.3	24.7	26.8	19.3	22.8
	Sudan grass + Soybean	22.7	26.0	29.1	21.7	24.9
	Sudan grass + Vetch + Sunflower	30.1	35.3	36.9	26.1	32.1
	Sudan grass + Soybean + Sunflower	27.3	37.1	39.2	26.3	32.5
	Sunflower + Vetch	26.8	42.4	43.6	25.8	34.7
	Sunflower + Soybean	36.1	35.5	36.1	35.1	35.7
	Sunflower + Sudan grass	25.6	34.3	36.7	24.6	30.3
	Sunflower	32.4	57.3	60.0	30.4	45.0
Background 1	Sudan grass	38.5	22.4	24.3	37.5	30.7
	Sudan grass + Vetch	25.8	28.6	30.5	24.8	27.4
	Sudan grass + Soybean	38.2	27.2	30.1	34.2	32.4
	Sudan grass + Vetch + Sunflower	27.4	40.8	42.3	23.4	33.5
	Sudan grass + Soybean + Sunflower	27.1	41.4	43.5	24.1	34.0
	Sunflower + Vetch	28.4	42.6	44.1	28.7	35.9
	Sunflower +Soybean	36.8	38.9	42.7	32.8	37.8
	Sunflower + Sudan grass	34.4	37.1	40.2	32.4	36.0
	Sunflower	47.6	59.0	62.1	46.6	53.8
Background 2	Sudan grass	32.5	32.5	33.1	30.5	32.2
	Sudan grass + Vetch	38.2	30.3	32.4	36.2	34.3
	Sudan grass + Soybean	36.7	41.3	43.8	35.7	39.4
	Sudan grass + Vetch + Sunflower	35.3	45.6	48.7	34.3	41.0
	Sudan grass + Soybean + Sunflower	37.1	47.2	47.9	33.1	41.3
	Sunflower + Vetch	51.0	42.3	44.6	49.0	46.7
	Sunflower +Soybean	52.1	42.5	43.7	48.1	46.6
	Sunflower + Sudan grass	52.2	43.3	45.1	50.2	47.7
	Sunflower	49.6	61.1	62.5	47.6	55.2
	LSD_{05}. tot.	0.16	0.11	0.15	0.19	

In Sudan grass stands with soybean, enrichment with fodder protein ranged within 6.58%–10.48% when compared with Sudan grass grown alone.

With the application of fertilizers, the values of the content of crude protein were steadily increasing: in the Background 1 and 2 treatments they increased by 15%–44% and 31%–60% relative to the control value, respectively. Among the mixtures, a favorable treatment was sunflower + soybean, which formed an average of 35.7–46.6 t/ha of green phytomass. The mixture of sunflower and vetch was inferior in productivity by 2%–5%, and at a high level of mineral fertilization, no difference in productivity was observed between the two-component mixtures.

The fodder value of feed is known to depend largely on the chemical composition of green phytomass and primarily on the content of biologically valuable protein in the feed [7]. Laboratory analysis of phytomass revealed that, on average, 5.49%–12.01% of crude protein accumulated during the years of studies in dry matter of the green phytomass harvest.

Sunflower planting with vetch or soybean when mown for silage accumulated approximately 11.02%–11.82% and 11.76%–12.98% more crude protein, respectively, than sunflower grown alone, exceeding the monoculture of sunflower when using this indicator by 13.0%–45.0% (Table 3).

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Table 3: Chemical analysis of mixtures when mown for silage (%, average for 2011–2014)

Treatment		Crude protein	Crude fiber	Crude fat	Crude ash
Control	Sudan grass	6.32	24.68	2.11	3.08
	Sudan grass + Vetch	7.92	26.74	2.78	4.05
	Sudan grass + Soybean	8.46	20.31	3.01	5.52
	Sudan grass + Vetch + Sunflower	9.13	26.10	2.67	4.11
	Sudan grass + Soybean + Sunflower	9.65	26.31	2.63	5.38
	Sunflower + Vetch	11.02	27.54	2.95	5.98
	Sunflower + Soybean	11.76	27.15	3.03	8.40
	Sunflower + Sudan grass	8.81	26.51	2.68	7.14
	Sunflower	8.12	28.74	2.96	6.97
Background 1	Sudan grass	6.89	25.88	1.84	5.39
	Sudan grass + Vetch	8.06	27.03	2.15	4.43
	Sudan grass + Soybean	9.07	18.70	2.76	5.41
	Sudan grass + Vetch + Sunflower	9.67	27.56	2.76	6.01
	Sudan grass + Soybean + Sunflower	10.76	28.03	2.86	6.14
	Sunflower + Vetch	11.67	27.61	2.78	6.22
	Sunflower + Soybean	12.84	27.93	3.14	7.70
	Sunflower + Sudan grass	9.25	26.62	3.05	7.36
	Sunflower	9.12	29.01	3.11	6.34
Background 2	Sudan grass	7.21	26.24	1.79	7.03
	Sudan grass + Vetch	8.85	27.47	2.32	5.05
	Sudan grass + Soybean	9.79	22.71	2.57	6.30
	Sudan grass + Vetch + Sunflower	10.38	27.91	2.69	4.75
	Sudan grass + Soybean + Sunflower	11.63	27.98	2.95	6.98
	Sunflower + Vetch	11.82	28.14	2.64	6.27
	Sunflower + Soybean	12.98	28.52	3.19	8.53
	Sunflower + Sudan grass	10.53	27.11	3.12	7.72
	Sunflower	10.32	29.77	3.19	8.56

Including soybean and vetch in cenoses with Sudan grass increased the content of fodder protein in dry phytomass by an average of 20%–31% when compared with that for single-species planting of Sudan grass. The greatest amount of protein (increased by up to 11.63%) was observed in the three-component mixture with soybean and sunflower (Table 4).

Table 4: Chemical analysis of green phytomass when mown for haylage (%, average for 2011–2014)

Treatment		Crude protein	Crude fiber	Crude fat	Crude ash
Control	Sudan grass	5.49	23.89	1.32	2.99
	Sudan grass + Vetch	8.92	21.44	2.12	3.41
	Sudan grass + Soybean	9.53	20.11	2.24	4.24
	Sudan grass + Vetch + Sunflower	9.03	26.98	2.09	5.67
	Sudan grass + Soybean + Sunflower	11.01	26.15	2.19	7.28
Background 1	Sudan grass	6.56	23.64	1.38	3.14
	Sudan grass + Vetch	9.06	21.60	2.37	3.67
	Sudan grass + Soybean	10.19	20.36	2.53	4.86
	Sudan grass + Vetch + Sunflower	10.26	27.12	2.20	5.87
	Sudan grass + Soybean + Sunflower	11.31	26.43	2.31	7.59
Background 2	Sudan grass	7.13	24.05	1.56	3.91
	Sudan grass + Vetch	9.63	24.87	2.63	5.13
	Sudan grass + Soybean	9.98	23.28	2.81	6.61
	Sudan grass + Vetch + Sunflower	11.13	27.64	2.48	6.05
	Sudan grass + Soybean + Sunflower	12.01	26.94	2.53	7.41

Fiber content serves as another important characteristic of feed because excess fiber reduces the nutritional value of feed and the efficiency of the use of metabolic energy. Meanwhile, a shortage of fiber results in dysfunction in the digestive systems of animals, and the synthesis of low-molecular weight fatty acids that determine the quality of milk is blocked when fiber is in short supply [1].

In the present study, the proportion of fiber in phytomass depended on the species composition of the grass stand. The smallest amount of fiber was accumulated by the green phytomass of the two-component mixture of Sudan grass and soybean, which was 19.11%–20.68% and 20.31%–22.71% when harvested for haylage and silage, respectively.

In three-component haylage mixtures, this figure reached 26.98%–27.64% with vetch, and 26.15%–26.94% with soybean.

In mixtures of Sudan grass with legumes harvested for silage, fiber made up an average of 20.31%–27.47% of dry accumulated phytomass, and in three-component mixtures fiber content ranged within 26.10%–27.98%. The dry matter of the treatments of two-component mixtures of sunflower with vetch or soybean contained the greatest amount of fiber, 27.54%–28.14% and 27.15%–28.52%, respectively.

The plants in various treatments also differed in the degree of content of ash elements. The largest amount of crude ash was noted in the dry matter of treatments involving sunflower; in Sudan grass phytomass and its mixtures with legumes its content was lower.

Dry matter content serves as an important indicator of the fodder value of any crop. The three-component mixtures provided the highest amounts of dry matter in the haylage block, ranging from 7.85–7.90 t/ha in the control treatment to 9.84–10.63 t/ha in the fertilizer treatments (Table 5).

Table 5: Fodder advantages of mixtures when mown for haylage (average for 2011–2014)

Treatment		Dry matter (t/ha)	Fodder unit (thous./ha)	Digestible protein (t/ha)	FPU (thous./ha)
Control	Sudan grass	6.47	5.05	0.27	3.88
	Sudan grass + Vetch	6.87	5.73	0.47	5.20
	Sudan grass + Soybean	7.20	6.23	0.52	5.72
	Sudan grass + Vetch + Sunflower	7.85	5.60	0.54	5.50
	Sudan grass + Soybean + Sunflower	7.90	5.78	0.66	6.19
Background 1	Sudan grass	7.22	5.67	0.36	4.64
	Sudan grass + Vetch	8.68	7.21	0.60	6.59
	Sudan grass + Soybean	8.87	7.62	0.69	7.25
	Sudan grass + Vetch + Sunflower	9.84	7.00	0.77	7.34
	Sudan grass + Soybean + Sunflower	9.94	7.21	0.85	7.88
Background 2	Sudan grass	8.50	6.60	0.46	5.60
	Sudan grass + Vetch	9.85	7.87	0.72	7.34
	Sudan grass + Soybean	9.92	8.45	0.75	7.70
	Sudan grass + Vetch + Sunflower	10.45	7.32	0.88	8.08
	Sudan grass + Soybean + Sunflower	10.63	7.60	0.97	8.65

Note: FPU, feed-protein units

In the silage block, the mono-crop of sunflower provided the maximum dry matter content per hectare, as much as 10.34 t/ha. Among the crop mixtures, the most productive in terms of dry matter content were two-component mixtures with legumes: vetch with 8.53–9.45 t/ha and soybean with 8.71–9.76 t/ha.

Among the treatments involving Sudan grass mown for haylage, the mixture with soybean provided the greatest fodder yield (up to 7.87 t/ha). The three-component grass stands provided slightly less fodder, or 0.7–1.13 t/ha less.

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An assessment of the advantages of fodder mixtures harvested for silage showed that Sudan grass mixed with leguminous crops had no advantages over the sunflower monoculture; however, the three-component mixtures proved to be 11.00%–21.00% more productive in terms of digestible protein (Table 6).

Table 6: Fodder advantages of mixtures when mown for silage (average for the years 2011–2014)

Treatment		Dry matter, t/ha	Fodder unit, thous./ha	Digestible protein, t/ha	FPU, thous./ha
Control	Sudan grass	7.29	5.56	0.33	4.44
	Sudan grass + Vetch	7.49	5.39	0.43	4.83
	Sudan grass + Soybean	8.41	7.24	0.55	6.38
	Sudan grass + Vetch + Sunflower	8.55	6.26	0.52	5.74
	Sudan grass + Soybean + Sunflower	8.48	6.18	0.59	6.04
	Sunflower + Vetch	8.53	5.99	0.68	6.38
	Sunflower + Soybean	8.71	6.19	0.74	6.78
	Sunflower + Sudan grass	8.29	6.00	0.53	5.63
	Sunflower	9.25	6.27	0.54	5.84
Background 1	Sudan grass	7.46	5.50	0.37	4.60
	Sudan grass + Vetch	8.22	5.86	0.48	5.31
	Sudan grass + Soybean	8.34	7.49	0.54	6.47
	Sudan grass + Vetch + Sunflower	8.96	6.29	0.62	6.26
	Sudan grass + Soybean + Sunflower	9.38	6.49	0.73	6.88
	Sunflower + Vetch	9.18	6.43	0.77	7.07
	Sunflower + Soybean	9.32	6.47	0.86	7.54
	Sunflower + Sudan grass	9.05	6.53	0.60	6.28
	Sunflower	10.06	6.76	0.66	6.68
Background 2	Sudan grass	7.75	5.65	0.40	4.84
	Sudan grass + V etch	8.77	6.17	0.56	5.88
	Sudan grass + Soybean	9.07	7.32	0.64	6.86
	Sudan grass + Vetch + Sunflower	9.33	6.48	0.70	6.73
	Sudan grass + Soybean + Sunflower	9.60	6.66	0.80	7.35
	Sunflower + Vetch	9.45	6.52	0.80	7.28
	Sunflower + Soybean	9.76	6.66	0.91	7.89
	Sunflower + Sudan grass	9.29	6.61	0.70	6.83
	Sunflower	10.34	6.79	0.77	7.24

Note: FPU, feed-protein units

Therefore, the three-component grass stands with sunflower yielded approximately 0.3 t/ha of protein, and this would allow farmers to balance the protein content in fodder within the limits of that required by livestock.

The cultivation of legumes combined with Sudan grass resulted in significantly increased protein content when compared with the control crops of cereals.

Similar patterns were observed in sunflower treatments; the inclusion of high-protein components in plant communities contributed to the largest content of digestible protein (0.52–0.91 t/ha) and fodder units (5.99–6.66 t/ha).

In sunflower cenoses, the greatest yield of feed-protein units (FPU) was provided by the mixture of sunflower with soybean or vetch. The three-component mixtures harvested for haylage provided 5.74–7.35 thousand FPU/ha with the maximum level of feed-protein combined with a high level of mineral fertilization, exceeding the control by 39%–46%.

Grain protein and the total, essential and non-essential amino acid content significantly increased with increasing nitrogen application [8]. Modern protein nutrition cannot be envisaged without considering the role of individual amino acids. Even with a general positive protein balance, the animal body may lack some specific proteins. This occurs because the absorption of individual amino acids is interrelated with other amino acids and a deficiency or excess of one amino acid may lead to a deficiency of another [9].

Proteins consist of more than one hundred kinds of amino acids, including the ten essential amino acids lysine, methionine, cystine, tryptophan, arginine, histidine, leucine, phenylalanine, threonine, and amino isovaleric acid. Animals cannot synthesize these essential molecules from other nitrogen-containing substances; therefore, they must consume them with food. Individual amino acids play extremely important roles in the process of metabolism. For example, animals use lysine to synthesize tissue proteins, arginine to synthesize urea and to produce semen in breeding males, histidine to generate hemoglobin and adrenaline, methionine in fat metabolism, and tryptophan for the renewal of plasma proteins [10].

Grain legumes are the most valuable vegetables in plant fodder in terms of their protein and essential amino acid content. In contrast to plant products containing nitrates (the protein content is increased in plants via the use of nitrogen fertilizers), the production of legumes is harmless to humans and animals; legumes have high nutritional and fodder values.

After determining the yield capacity, the fodder mixtures obtained in the present study were examined for amino acid content. The sunflower and soybean mixture was found to contain the largest amount of amino acids. For example, the control treatment produced 7.28 g/100 g of essential amino acids, which can be compared with 4.29 g/100 g in sunflower (Table 7).

Table 7: The content of essential amino acids in mixtures without the use of fertilizers (g/100 g of green phytomass, 2011–2014)

Amino acids	Sudan grass, vetch, sunflower	Sudan grass, soybean, sunflower	Sunflower, vetch	Sunflower, soybean	Sunflower, Sudan grass	Sunflower
Protein	8.50	9.90	8.00	13.3	8.10	7.60
Histidine	0.47	0.50	0.43	0.57	0.46	0.51
Threonine	0.60	0.61	0.54	0.71	0.55	0.52
Amino isovaleric acid	0.70	0.68	0.66	1.17	0.62	0.74
Methionine	0.10	0.11	0.15	0.30	0.11	0.08
Phenylalanine	0.74	0.94	0.85	1.12	0.80	0.67
Isoleucine	0.67	0.92	0.71	1.10	0.61	0.59
Leucine	0.74	1.23	0.74	1.31	0.73	0.55
Lysine	0.67	0.70	0.45	1.0	0.77	0.63
Total of essential amino acids	*4.69*	*5.69*	*4.53*	*7.28*	*4.65*	*4.29*

Usually, fodder is deficient in amino acids; however, levels of cysteine, methionine, and lysine are generally relatively high in the green phytomass produced by a mixture of sunflower and soybean, amounting to 0.2, 0.3, and 1 g/100 g, respectively (Table 8).

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Table 8: The content of nonessential amino acids in mixtures without the use of fertilizers (g/100 g of green phytomass, 2011–2014)

Amino acids	Sudan grass, vetch, sunflower	Sudan grass, soybean, sunflower	Sunflower, vetch	Sunflower, soybean	Sunflower, Sudan grass	Sunflower
Aspartic acid	0.92	0.93	0.90	1.04	0.63	0.73
Serine	0.07	0.1	0.06	0.92	0.06	0.09
Glycine	0.56	0.61	0.48	0.55	0.44	0.48
Arginine	0.47	0.4	0.41	0.81	0.44	0.28
Alanine	0.4	0.48	0.48	0.61	0.47	0.3
Tyrosine	0.67	0.79	0.47	0.88	0.55	0.61
Cysteine	0.06	0.11	0.12	0.16	0.06	0.12
Proline	0.46	0.75	0.5	0.78	0.62	0.49
Total of nonessential amino acids	*3.61*	*4.17*	*3.42*	*5.75*	*3.27*	*3.10*

The three-component mixture of Sudan grass, sunflower, and soybean also produced good results with 5.69 g/100 g of essential amino acids. The amino acids content in the three-component mixture was less than that in the two-component mixture because the contribution of amino acids from soybean decreased with the increase in the number of components; therefore, the protein content and the corresponding proportion of amino acids were lower in the two-component mixture.

The application of fertilizers resulted in varying degrees of increase in the amino acid content of fodder in all treatments of the experiment. The sunflower and soybean mixture provided the best results with total protein content of 17.6 g/100 g, which was five times greater than that of the control treatment. In this mixture, the maximum content of essential amino acids amounted to 9.41 g/100 g (Table 9). The total content of nonessential amino acids was also higher (5.75 g/100 g) in the mixture of sunflower and soybean in the non-fertilized treatment and was 8.16 g/100 g on the mineral background.

Table 9: The content of amino acids in mixtures with the use of fertilizers (g/100 g of green phytomass, 2011–2014)

Amino acids	Sudan grass, vetch, sunflower	Sudan grass, soybean, sunflower	Sunflower, vetch	Sunflower, soybean	Sunflower, Sudan grass	Sunflower
Protein	10.9	12.7	8.9	17.6	9.9	8.7
Histidine	0.66	0.87	0.54	0.81	0.57	0.66
Threonine	0.72	0.7	0.56	1.02	0.5	0.55
Amino isovaleric acid	0.75	0.89	0.94	1.37	0.89	0.81
Methionine	0.23	0.23	0.29	0.54	0.3	0.16
Phenylalanine	0.72	1.1	0.56	1.58	0.9	0.73
Isoleucine	0.69	1.04	0.76	1.41	0.81	0.71
Leucine	0.8	1.38	0.83	1.62	0.81	0.63

Lysine	0.8	0.9	0.79	1.06	0.98	0.79
Total of essential amino acids	*5.87*	*7.27*	*5.27*	*9.41*	*5.76*	*5.04*
Aspartic acid	1.04	1.1	1.02	1.5	1.24	0.94
Serine	0.82	0.7	0.26	1.3	0.1	0.12
Glycine	0.43	0.65	0.73	0.99	0.46	0.5
Arginine	0.97	0.62	0.36	1.34	0.44	0.36
Alanine	0.64	0.81	0.47	0.93	0.55	0.42
Tyrosine	0.61	0.87	0.49	0.93	0.57	0.63
Cysteine	0.07	0.12	0.11	0.18	0.08	0.11
Proline	0.46	0.77	0.59	0.99	0.81	0.53
Total of nonessential amino acids	*5.04*	*5.64*	*4.03*	*8.16*	*4.25*	*3.61*

Here, among all of the treatments, the maximum content of aspartic acid, serine, and arginine was 1.04, 0.92, and 0.81 g/100 g without the use of fertilizers and 1.5, 1.3, and 1.3 g/100 g with the use of mineral fertilizers, respectively.

When comparing the maximum yields for all the years of the present research study, pure crops of sunflower provided the lowest amino acid content. Mixtures of sunflower with spring vetch were inferior in amino acid composition to mixtures with soybean but considerably exceeded the amino acid content of sunflower alone.

CONCLUSIONS

The cultures and mixtures under study can produce up to 32.3 t/ha of green phytomass when mown for haylage and up to 55.2 t/ha for silage. The rates of calculated fertilizer application for the planned yield of 4.5–5.0 thousand fodder units increased the productivity of crops by 16%. An increase in the level of mineral fertilization to 6.0–6.5 thousands fodder units contributed to an additional gain of up to 4.8 t/ha of aboveground phytomass when compared with the control.

The use of mixed crops employing traditional crops with legumes significantly enriched the phytomass of mixtures with greater amounts of protein, fat, and ash elements. Complex cenoses on the accumulation of digestible protein are much more productive than mono-planting of Sudan grass or sunflower and provided a greater yield of fodder units and a good balance for the protein. In treatments with Sudan grass, the highest quality crop was formed when mixing Sudan grass with both sunflower and a legume component; therefore, these mixtures are recommended for the production of haylage as the most productive treatment in this study.

In treatments with sunflower, the mixtures with soybean or vetch proved themselves to be the highest quality and most productive; therefore, it is reasonable to use them for harvesting for silage if mown during the blooming of sunflower.

The green phytomass of a mixture of sunflower and soybean produced the optimal amino acid composition. Fertilizer application resulted in an increase in the content of almost all amino acids in the studied treatments of mixtures, where the highest values were observed in a mixture of sunflower and soybean. Along with this treatment, high levels of amino acids were seen in a mixture of sunflower with soybean and Sudan grass.

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