A1 Creating an innovative multi-species long-lived grassland mixture

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Goal: To develop a permanent grassland concept (HSG-grassland) based on local conditions. Aiming for high nutritional value, productivity, phytomass and balanced distribution of mineral elements, as well as botanical composition of grasses suitable for fattening cattle with high intramuscular fat in the last phase of the production cycle.

INNOVATION ACTIVITY A1 IT1: Development of concept grassland seed mixtures

Purpose: The purpose of this activity was to develop an innovative seed mixture for long-lived diverse grasslands suitable for the Estonian context. Deep-rooted grasses and legumes with high nutritional value best suited to Estonian conditions were identified for the establishment of permanent grasslands, taking into account availability and cost when creating seed mixes. Seed mixtures were selected that are suitable for use in organic production, i.e. productive without synthetic fertilisers. For the development of seed mixtures, permanent grasslands with different soil types were selected for site-specific test fields.

Evaluation: The goals of this innovation activity were fully achieved.

The actions carried out within IT1 were:

- A literature review was compiled on what kinds of species-rich grassland mixtures have been studied and used in various other countries.
- Test sites were selected, and soil sampling and inventory of existing grassland were carried out at the selected test sites.
- A seed mixture for Estonian grassland was designed and sown at the test sites.

Literature review of grass seed mixtures for beef cattle

What was done

Based on the literature, ETKI researchers reviewed studies from Finland, Denmark, England and other European countries, as well as the results of research by scientists from the USA, Canada and New Zealand on the preparation of grassland seed mixtures suitable for beef cattle.

Results

Uno Tamm PhD, Estonian Plant Breeding Institute compiled the literature review titled ”*Kontsept - rohumaa seemnesegude väljatöötamine. ROHUSÖÖTADEL PÕHINEV LIHAVEISEKASVATUS*”. The review is available for public download here. An English summary of the review is presented in Appendix 1.

The review concludes that a multi-species pasture seed mix with grasses, legumes and herbs is the preferable option. Having a variety of plant species growing in grasslands is beneficial for animal health and growth, as well as offering environmental benefits, such as biodiversity and nitrogen fixation. Plant species that are often found in well-rounded pasture seed mixes include for example clovers, alfalfa, fescues, bluegrass, bird's-foot trefoil, ryegrass, chicory and caraway.

Grass fodder (pasture grass, silage, hay) is known to provide young animals with an average gain of up to 1000 g/day. Grazing beef usually grow well in spring and early summer when the nutritional value of the fodder is high, but slower in mid-summer and autumn. Properly organized grazing can keep grass in a constant vegetative phase with low fiber and sufficient

energy and protein content. Maintaining pastures by mowing, harrowing, and using paddock or rotational grazing can improve grass quality in the autumn. Of those options, rotational grazing that adapts to the forage availability is the most cost effective and provides the highest nutrition. Areas previously used for silage or hay can also be used as fall pastures, keeping in mind that adequate recovery time is needed after cutting.. For winter feed, optimal systems of growing and harvesting fodder crops can ensure that grass fodder meets the nutritional requirements of animals by providing the necessary energy density. On average, pasture grass has the highest metabolizable energy content at 10 MJ kg-1, while silage and hay have lower levels at 9 MJ kg-1 and 8 MJ kg-1, respectively. Protein content is highest in pasture grass and lowest in hay.

Selection and planning of experimental areas

What was done

ETKI researchers selected 10 experimental areas from among the field arrays proposed by the cluster members in the spring of 2018. The selection was based on different soil types. It was also considered important that the test sites would include a natural body of water so that the animals had free access to water.

During the initial familiarization with the future test sites, the existing plant types and species composition were inventoried and soil samples were taken. The soil samples were taken according to the generally accepted guide and sent to the PMK laboratory for analysis.

Results

The soil types and plant variety of the eleven selected test sites are briefly described below. The soil analysis results of the test sites are presented in Table 1. Based on the results of the soil analyses, a plan for liming and fertilizing with manure was also developed for the test sites (see IT2).

Farm E 1 field array no. 63749765391

Humus-rich, nutrient-rich, well-structured temperate soil. Generally suitable for growing many grasses. Species-rich grassland. Cultivated species included meadow foxtail, cock’s foot and white clover. Among the natural species and weeds there were dandelion, ground elder, nettle, buttercups, sedge species, meadowsweet, cow vetch, quaking grasses, st. John’s wort, lady's mantles, water avens and various species of rumex (dock).

Farm E 2 field array No. 63749799781
Humus-rich, nutrient-rich, non-compacted soil with a good structure. Moisture varies from moderately moist to excessively moist. Generally suitable for growing many grasses. Grassland with a variety of species. Cultivated species included meadow foxtail, cock's foot and white clover. Among the natural species and weeds there were dandelion, dandelion, ground elder, nettle, buttercups, sedge species, meadowsweet, cow vetch, quaking grasses, st.John's wort, lady's mantles, water avens and various species of rumex (dock).

Farm H field array no. 64840335699
Moderately eroded (risk of erosion) loamy soil. Among the cultivated species, there were cock's foot, bluegrass, white clover and a few alfalfas. Among the natural grasses there were zigzag clover, meadow vetchling, cow vetch. Weeds were abundant with meadow buttercup, wild carrot, plantains and dandelion.

Farm F field array no. 65738612788
An old cultivated pasture, in which a relatively large number of foxtails have been observed. Among the cultivated species there were meadow foxtails, timothy, meadow fescue, bluegrass and white clover. Weeds in the pasture included buttercups, water foxtail, silverweed, tufted hairgrass and a small amount of other weeds. Legumes were practically absent due to the excessive acidity of the soil.

Farm C 1 field array no. 63639167538
The soil is humus-poor and on the dry side, compacted and not very active. Cultivated species included cock's foot, red fescue, bluegrass and red clover. Of the natural leguminous plants, only meadow vetchling was present and of the grasses common bent. Weeds in the pasture included dandelion and buttercup. A relatively species-poor and sparse area.

Farm C 2 field array no. 63639146571
The soil is low in humus and acidic, but rich in basic nutrients. Among the cultivated species, there were cock's foot, bluegrass, red fescue, white and red clover, and a small amount of meadow foxtail. Among the natural grasses there were common bent, different herbs such as Equisetum and yarrow.

Farm C field array no. 61742687196
Loamy compacted soil, generally suitable for growing all grasses. At the moment, the grassland was heavily overgrazed. Cultivated species included cock's foot, white and red clover, meadow fescue, blue grass, meadow foxtail and red fescue. Among the natural species, there were common bent and hop clover. Weeds in the pasture included abundant dandelions, rough bluegrass and various species of rumex (dock).

Farm D 1 field array no. 61957593489
Liquefied, acidic soil. Sufficient basic nutrients for grass growth, but low humus content. Grassland sown 7-8 years ago. At the moment red and white clover, timothy, pasture ryegrass and bluegrass have been preserved, but all to a small extent. Heavily weeded with dandelion, Russian dock, yarrow, echium and buttercup.

Farm D 2 field array no. 62057513876

Leached soil. Severely suffered from drought. Cultivated species included red clover, cock's foot (to a small extent) and alfalfa. Among the natural legumes cow vetch was present. Heavily weeded with dandelions, yarrow and dock.

Farm D 3 field array no. 62057506432
Leached soil. Among the cultivated species there was white clover and some alfalfas. Weeded with dandelion, coltsfoot, convolvulus, dock and buttercup.

Farm B no 50250669731
Pseudo-lithified soil. Former cultivated pasture, mostly timothy and foxtail. Among the weeds there was a lot of tufted hairgrass, silverweed, buttercup, lady's mantles and others.

Table 1. Soil analysis results of test sites

Test site no.	pH	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	Cu mg/kg	Mn mg/kg	B* mg/kg	C_{org} %*
63749765391	6.7	128	123	3502	306	2.2	117	1.51	2.9
63749799781	6.7	21	90	5685	735	3.9	175	2.59	6.7
64840335699	5.7	44	148	1120	145	0.8	100	0.53	1.8
65738612788	5.2	16	268	2274	229	0.5	62	0.69	3.3
63639167538	7.1	44	121	5983	162	1.0	80	0.35	1.9
63639146571	5.5	230	260	1278	129	1.4	139	0.64	1.9
61742687196	6.6	78	169	2344	227	0.8	107	0.62	1.6
61957593489	4.9	184	258	589	57	0.5	112	0.31	1.5
62057513876	5.3	144	124	836	62	0.6	104	0.33	1.6
62057506432	5.9	67	131	2086	63	0.8	135	0.85	2.1
50250669731	5.1	24	412	2496	699	1.7	27	1.23	4.6

*These results were obtained using non accredited methods.

Developing a seed mixture for Estonian use

What was done

Based on the aforementioned scientific review, which emphasizes the importance of species richness, the direction taken in this project was to use a species-rich grass seed mixture for establishing Estonian grassland. The aim was to use local varieties as much as possible.

Results

The seed mixture was developed and sown in 2019 at the test sites described above, as well as ETKI test sites Jõgeval and Saku. 13 species were included in the mixture: 30% legumes and 70% grasses. The composition of the seed mixture is presented in Table 2.

When developing the seed mixture, it was ensured that it would be suitable for organic production. It was also taken into account that if the clover disappears its place will be taken by the alfalfa "Juurlu", which develops slowly during the first years. Also, when Italian ryegrass disappears, its place can be taken by pasture ryegrass, as well as sedge grass and red fescue, which also ensure a long-term and strong cover suitable for grazing. When adding chicory, its anti-parasitic and soil-improving properties were taken into account.

Table 2. Seed mixture developed for Estonian grasslands

Type	Variety	Quantity, kg/ha
Alfalfa	Juurlu	2.5
Red clover	Jõgeva 433	3
Alsike clover	Jõgeva 2	1
White clover	Jõgeva 4	1
White clover	Tooma	1
Bird's-foot trefoil	Leo	0.5
Timothy	Tika	5
Meadow fescue	Arni	4
Bluegrass	Esto	2
Red fescue	Kauni	1
Italian ryegrass	Talvike	3
Pasture ryegrass	Raite	2
Tall fescue	Barelite	4
Chicory		0.3
	Total:	30.3

INNOVATION ACTIVITY A1 IT2: Developing a concept grassland establishment methodology

Purpose: Developing methodology for sowing and maintenance of concept grassland seed mixes.

Evaluation: The goal was achieved. The methodology chosen is conventional, plough-based establishment of grasslands, as it was based on the real capacity of farmers and the available technology. Based on the farmers' monitoring, the emergence was good, despite the drought. All farms participating in the experiment carried out the predetermined activities.

The actions within IT2 were:

- Liming and fertilizing standards developed

- Tillage works carried out at test sites
- Soil sampling carried out at test sites

Liming and fertilizing standards

What was done

The liming and fertilizing standards were developed by the researchers of the Agricultural Research Center and ETKI (Dr. Valli Loide, specialist in fertilizer and lime use) according to the results of the soil analyses of the test sites (see Table 1 on page 5).

Results

Table 3 lists the recommended amounts of lime and manure for each test site. Liming was done with a mixture of Eivere limestone 37.5%, Rõstla dolo stone 37.5% and Tallinna Elektrijaam wood ash 25%.

Table 3. Recommended amounts of lime and manure for test sites

	Recommendation t/ha	
Test site no.	Manure	Lime
63749765391	30-35	0
637497999781	30-35	0
648403335699	30-35	4.5-6
65738612788	30-35	5+5
63639167538	30-35	0
63639146571	30-35	0
61742687196	30-35	0
61957593489	30-35	4.5-6
62057513876	30-35	4.5-6
62057506432	30-35	0
50250669731	30-35	5+5

Tillage

What was done

Tillage work for establishing the experimental grasslands was first done on test sites in the autumn of 2018 by the farmers with the existing machinery. Tillage works were again carried

out at test sites in the spring of 2019. OÜ Prees was chosen as the service provider for this work.

Results

A set of instructions was created for farmers to establish an experimental grassland:

- The sod is crushed with a shallow disk harrow, if necessary twice, with discs at an angle of 30 degrees;
- Manure is spread at the rate of 30–35 t/ha;
- It is recommended to plow with a double furrow plow at the selected depth with a slice width ratio of not less than 2/3 (to ensure that the slices close!);
- Cultivate a sufficient number of times to achieve the correct seed bed;
- Depending on the weather, pre- and post-sowing harowing is necessary;
- Sow as early as possible in the spring: plants sprout at the expense of spring soil moisture;
- Use overmowing to control weeds;
- It is not advisable to graze grassland in the year of establishment; grass mass can be made into silage.

Soil sampling

What was done

In the spring of 2019, one month after establishing the grasslands, another set of soil samples were taken at the test sites. In 2022, another set of samples was taken on only 4 fields of 4 participating farms.

Results

Preliminary soil analysis results showed an improvement in soil pH and a change in nutrient content. Below the test results for 2019.

Table 4. Analysis results of the first-year soil samples after establishment

Test site nr.	Test farm	pH(KCl)	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	Cu mg/kg	Mn mg/kg	B* mg/kg	Corg * %

62241987170	Farm A	4,4	111	87	403	63	1,1	89	0,19	1,4
61742687196	Farm A	6,6	78	169	2344	227	0,8	107	0,62	1,6
50250669731	Farm B	5,1	24	412	2496	699	1,7	27	1,23	4,6
63639167538	Farm C	7,1	44	121	5983	162	1,0	80	0,35	1,9
63639146571	Farm C	5,5	230	260	1278	129	1,4	139	0,64	1,9
63639113733	Farm C	4,7	178	91	465	44	0,6	61	0,19	1,2
61957593489	Farm D	4,9	184	258	589	57	0,5	112	0,31	1,5
62057513876	Farm D	5,3	144	124	836	62	0,6	104	0,33	1,6
62057506432	Farm D	5,9	67	131	2086	63	0,8	135	0,85	2,1
63749765391	Farm E	6,7	128	123	3502	306	2,2	117	1,51	2,9
63749799781	Farm E	6,7	21	90	5685	735	3,9	175	2,59	6,7
63749756675	Farm E	5,3	22	84	1579	202	1,3	63	0,81	2,9
65738612788	Farm F	5,2	16	268	2274	229	0,5	62	0,69	3,3
65538608861	Farm F	6,7	178	304	3751	686	0,7	121	2,84	5,0
64840335699	Farm H	5,7	44	148	1120	145	0,8	100	0,53	1,8
64740294965	Farm H	6,7	91	165	1504	243	0,5	121	0,37	1,3

Table 5. Soil test results 2022, with red indicating decreases and green increases compared to 2019.

Test site nr.	Test farm	pH(KCl)	P mg/kg	K mg/kg	Ca mg/kg	Mg mg/kg	Cu mg/kg	Mn mg/kg	B* mg/kg	Corg * %
61742687196	Farm A	6,1	80	135	1288	136	1,0	133	0,6	1,6
62057506432	Farm D	5,7	77	73	1465	40	1,2	95	0,71	2,0
63749765391	Farm E	6,6	47	93	2257	227	1,5	117	0,91	2,1
64740294965	Farm H	6,7	37	131	1671	147	1,1	122	0,58	1,6

Comparing the soil test of 2019 with those of 2022 reveals that most of the value declined. In terms of pH, there are slight decreases for 3 of the 4 test sites. In particular the calcium values declined sharply on farm A, D and E, while they increased slightly on farm H. Additionally, magnesium values also dropped significantly on all farms. Copper values for farm H more than doubled, while Boron values also rose significantly. None of these fields had any lime applied to them, only manure.

These test results show strong shifts for certain nutrients and minerals, which are too large of a magnitude to have happened due to removal of nutrients and minerals through grazing or forage harvesting. The main explanation to be found for these differences is that the soil

samples were taken in different parts of the field in 2019 than in 2022. Due to the large variance of soil types and qualities within single fields in Estonia, this is the most likely explanation.

INNOVATION ACTIVITY A1 IT3: Improving the concept grassland

Purpose: To determine the qualitative and quantitative yield of the concept grassland based on the yield of grasses and fodder analyses. This is used to improve the methodology of the concept and establishment of the created innovative grassland.

Evaluation: The goal was achieved. The harvest was set for 2020/2021 and at Farm E also for 2022.

The actions within IT3 were:

- Silage samples
- Information material & advice for farmers
- Botanical analysis of the test sites

Silage samples

What was done

It is not reasonable to determine qualitative and quantitative yield of the grasslands in the year of their establishment, as the impact of weeds is high and many slowly developing species do not yet manifest themselves in vegetation. However, silage was made and silage samples were taken from test sites, as these results are related to parallel IT activities 9-16. Table 6 below presents these results.

Silage made from the established grasslands are analyzed within IT4 (2020) and IT6 (2021). Based on the results of the two years following the year of establishment, it is possible to estimate the quantitative and qualitative yield of the experimental grasslands.

Results

Table 6. Analysis results of the first-year experimental grasslands silos

S no.	Silo	pH	KA %	TP%	NDF %	ADF %	DD M%	DMI %	ME MJ/	Starch/sugars %	Silage cut	Silage preparation date	Description of vegetation
1	Farm B	5,51	64,09	9,66	61,53	36,83	60,21	1,95	9,3	21,12	1	3-4 July	Naturally grassy meadow hay.
2	Farm B	4,76	30,81	12,74	54,36	24,22	62,25	2,21	9,7	21,59	1	6-7 June	40% red clover 60% various grasses.
3	Farm D	5,1	59,56	11,02	53,59	38,07	59,25	2,24	9,1	27,78	1	20 June	60% of the grass mass is: white clover Rivendel 2.5kg/ha timothy Jõgeva 54 9.5 kg/ha; bluegrass Balin kg/ha; pasture ryegrass Calibra 4kg/ha; pasture ryegrass Mathilde 4kg/ha. Most of the new grasslands in Tranže have been established (as undersowing) by a mixture of very different grasslands (red clover + timothy; permanent grassland, mostly grass; alfalfa front established as a pure crop)
4	Farm D	4,88	50,51	13,66	48,21	33,43	62,86	2,49	9,8	27,59	2	4-27 July	Grassland with new sowing + chicory. Trench at the bottom is in addition to the experimental grassland, a second cut of red clover established as a mono culture (ca. 75 cm layer).

5	Farm D	5,25	53,32	14,49	51,37	31,31	64,51	2,34	10,1	25,28	2	7-23 July	Red clover+ timothy about 40%; lucerne first year weed-rich cut (Chenopodium, etc.) established as a pure crop about 20% and grassy permanent pasture (established as a mixture of different varieties of ryegrass+Poa pratensis+timothy about 30%; Phalaris arundinacea about 10%).
6	Farm C	4,9	30,6	13,6	44,54	34,05	62,37	2,69	9,7	29,32	2	15 Aug	Newly sowed grassland + chicory
7	Farm G	4,21	31,65	7,18	58,25	37,36	59,79	2,06	9,2	26,35	1	11 July	A mixture of grasses (established in 2012)
8	Farm G	5,46	40,57	14,42	48,76	32,14	63,86	2,46	10,0	26,7	1	10 June	Established in 2017. Red clover Jõgeva 433 14% timothy - Tika – 21%; Pasture ryegrass - Raite 30%; meadow fescue -Arni- 21%; white clover -Rive 7%; bluegrass -Esto – 7%
9	Farm G	4,78	26,61	18,2	42,53	31,97	63,99	2,82	10,0	24,8	2	Mid August	Newly sowed grassland + chicory
10	Farm G	5,27	54,15	9,27	59,1	36,62	60,37	2,03	9,3	23,97	1	17 June	Established in 2018. Red clover Jõgeva433 14%; timothy -Tika - 21%; pasture ryegrass-Raite - 30%; meadow fescue -Arni- 21%; white clover -Rivendel -7%; bluegrass -Esto – 7%
11	Farm F	4,66	34,46	12,67	51,34	33,27	62,98	2,34	9,8	25,00	1	8-9 June	Natural grassland-grass and some legume.
12	Farm F	5,14	32,44	13,77	52,44	37,04	60,05	2,29	9,3	18,63	2	September	Newly sowed grassland + chicory
13	Farm C	4,92	33,66	12,96	52,26	37,96	59,33	2,3	9,1	18,67	2	26 Aug	Newly sowed grassland + chicory

14	Farm C	4,69	41,8	18,65	42,19	31,95	64,01	2,84	10,0	28,14	2	23 July	Cultivated grassland of the second year
15	Farm E	4,28	23,5	13,31	46,87	29,91	65,6	2,56	10,3	29,01	1	8 June	Silo Classic mix, established in 2017 with undersowing, clover reduced. Red clover diploid-25%; timothy 20%; meadow fescue-35%; pasture ryegrass -20
16	Farm E	5,14	29,48	14,23	44,51	32,14	63,86	2,7	10,0	28,58	2	18.Aug	Newly sowed grassland + chicory
17	Farm H	4,97	29,87	17,18	46,27	31,86	64,08	2,59	10,0	22,86	2	20 Sep	Newly sowed grassland + chicory
18	Farm H	5,05	25,18	19,55	43,56	35,1	61,56	2,75	9,59	22,34	1	10 Aug	Newly sowed grassland + chicory
19	Farm H	4,83	43,04	13,91	54,07	36,78	60,25	2,22	9,3	22,71	1	15 June	Red clover (5kg/ha) timothy (7.5kg/ha) meadow fescue (5kg/ha) pasture ryegrass (7.5 kg/ha)
20	Hay Farm A		83,88	10,13	60,17	36,28	60,64	1,99	9,42	22,86		before 24.06	Natural-grass (reed canary grass)
21	Hay Farm F		83,44	4,69	66,69	39,8	57,9	1,80	8,9	21,96			Natural-grass
22	Hay Farm C		81,95	8,08	65,29	38,98	58,54	1,84	9,0	20,68			Natural-grass
23	Hay Farm E		81,4	5,88	65,7	37,48	59,7	1,83	9,24	22,11			Mainly pasture ryegrass (originally there was fescue and white clover in the mix, now they are not visible).

Informational material & advisory

What was done

Based on the analysis reports, research partner Marika Oeselja (Agro Consultant MTÜ) composed the silos comparison table (Table 6 above), prepared informational material about the quality of silage and hay to producers and advised the producers as necessary. An English summary of the informational material for farmers is presented in Appendix 2.

Results

Informational material on silage was compiled covering the following topics:

- **Silage acidity pH**: Silage quality evaluation should consider both dry matter and pH levels. Lower pH indicates more acidity, which inhibits bacteria growth in wet silage, but high pH in drier silage may not indicate poor quality, but it may be less stable. Legume silage has a higher pH and lasts longer.
- **Crude protein (TP%)**: The protein content of feed indicates the growth phase when grass was harvested and includes nitrogen-containing compounds from proteins and non-protein compounds. ADF increase is the best indicator for silage analysis. TP 11-14% in silage is enough for a lactating cow, while higher protein and energy silage is suitable for fattening animals for higher growth rates and muscle development.
- **Acid fibers (ADF %)**: ADF indicates the digestibility of grass and fodder, with lower percentages being better. ADF levels increase with plant age and lignin content, making the feed less digestible. Good silage has ADF levels below 35% for legumes and 37% for grasses.
- **Net neutral fiber (NDF %)**: NDF measures plant cell wall substances and affects feed intake. NDF below 46% is good, while above 61% is bad. Legumes should have NDF below 46%, while grasses should have NDF below 55%.
- **Digestive dry matter content (DDM %)**: Feed nutrients are not completely absorbed by animals, and the undigested portion is excreted as faeces. The digestion coefficient determines how much of the nutrient is digested and absorbed, with higher values indicating more valuable feed. Digestibility depends on factors such as animal and feed characteristics, and organic matter with a coefficient above 65% is considered very good.
- **Dry matter food (DMI %) to create per body weight**: The potential feed intake of an animal is affected by factors such as the composition of the ration, silage fermentation products, and digestibility.
- **Relative feed value RFV**: The value given provides an estimate of the relative feed value. A value over 100 indicates a better feed value and quality.
- **Metabolizable energy ME MJ/ kg dry matter**: Relative feed value (RFV) is used to indicate the quality of grass feed, with energy content depending on digestible nutrients and harvesting time. A good silage should have a metabolizable energy (ME) content of more than 9.5 MJ, which is necessary for fattening animals and lactating cows.
- **Starch + sugars %**: To promote growth and muscle development in fattening animals, high metabolizable energy content in grass feed is crucial, achieved through

high starch and sugar content. However, in final fattening rations with much concentrate, starch and sugar indicators should be considered to avoid rumen acidity and acidosis.

General informational material on hay was also compiled. This covered advice on the following topics:

- **Harvesting and drying**: Factors affecting hay quality include botanical composition, growth phase at harvest time, fertilization, soil, weather, and storage conditions. Legumes such as clover and alfalfa have high nutritional value. Drying conditions affect hay quality, and good drying conditions are when humidity drops to 51-60% during the day. High-quality hay should contain at least 10% protein and 9.0 MJ/kg of metabolizable energy in dry matter.
- **Moisture and colour**: Hay's moisture content is evaluated by breaking and twisting it between hands. Dry hay (≤15%) feels rough, rustles, and breaks easily. Average dry hay (17%) feels soft and cooler, and plant stems do not break as easily. Moist hay (17-20%) doesn't rustle, and plant stems do not break even when bent repeatedly, while wet hay (20-23%) feels cold and has visible moisture. Hay shouldn't exceed 15% moisture to prevent mold. Harvesting and storage conditions can affect the color and nutritional value of hay.
- **Nutritional value**: Pregnant cows and heifers are especially sensitive to mold toxins. Calves need high-quality protein supplements if they are not getting enough from their mother's milk by six months of age. Young animals need grass feed with high energy and protein content. Late growth phase hay is not suitable for fast-growing young animals. Fattening animals need at least 10.5 MJ/kg of dry matter and 14% protein. Pregnant cows need better feed at the end of pregnancy and during lactation. Cereal flour or concentrated feed is necessary when feeding only low-nutritional-value hay.

Botanical analysis

What was done

ETKI researchers performed a botanical analysis of the amount of shoots and weight of the sown species in the experimental grasslands. The shoot analysis was done by taking 10 soil cores of 10 × 10 cm from each experimental site. A 10 × 10 cm drill was used to take soil samples. When counting the number of shoots, the sod was crushed, which made it easier to recognize the species. Apart from the sown species, also volunteer species were counted. The analysis results were calculated per 1 m². The total number of shoots indicates the density of the species in the pastures. This was done for 5 participating farms in 2020, 2021 and 2022.

The botanical weight analysis was done to study the dynamics of species over the years. An average sample was taken from the grassland, which was then sorted by species and weighed. The forage was cut from 10-15 places of each experimental site, in 3-5 cm wide and 40-50 long strips. From the total sample collected, 300-500 grams were separated for analysis after proper mixing. Fractions separated by analysis were immediately weighed. For the botanical analysis, samples were taken from the beginning of July to the middle of August, i.e. when the forage composition is most representative. This was done for 5 participating farms in

2020 and 2021. In 2022, only data from one farm was collected seeing the budget of the researchers ran out.

Results

The species establishment data was analysed in both the species composition compared to the sowing rate, as well as compared to the composition of previous years. We find that the composition of alfalfa, timothy, common fescue, kentucky bluegrass, red fescue, perennial ryegrass and tall fescue are all variable, not showing any clear trend across the different farms nor over the years.

When looking at the shoot analysis and analysing the data points compared to the sowing rate, we find that white clover established itself in higher rates, while red clover, pink clover and italian ryegrass established themselves in lower rates. However looking at the weight analysis for these species does not reveal any trend.

For trefoil the methodology using weight shows variable results, while the methodology measuring shoots shows a stable composition in line with both sowing rate and previous years. For chicory the methodology using weight shows an increase, while the methodology measuring shoots shows a stable composition in line with both sowing rate and previous years.

If we analyse the data from a farm specific lens, we also can't find any clear trend in terms of establishment. This can largely be attributed to a lack of data for the weight methodology which only has data spanning 2 years. This makes cross analysis of both methodologies challenging given that analysing two years of data cannot give any reliable indication of trend or direction, especially given the extreme weather of 2021.

In general, there is no clear indication of species performance when analysing the data from a species perspective across all farms. This is also to be expected seeing that every farm has a different micro-climate and different soils, and thus different results. As such, it is very unlikely that one specific seed mixture will perform well in all pastures. Nature is far too

complex to have single so-called silver bullet solutions that work everywhere. Rather, all farming practices have to be tailored to the specific conditions and context of each farm.

Table 7. Botanical shoots analysis results

Place	Seeding rate		Puutsa			Haabsaare			Kirbla			Pariismar			Voitk		
Year	kg/ha	%	2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022	2020	2021	2022
Alfalfa	2.5	8.3	1.3	3.3	0.6	1.4	9.2	5.2	2.1	13.1	8.5	5.3	7.4	1.2	2.5	15.0	3.6
White clover	2.0	6.6	11.0	15.9	18.7	16.9	16.6	11.0	25.0	9.3	9.0	10.6	10.6	11.6	16.9	21.0	25.8
Red clover	3.0	9.9	6.0	5.2	1.3	2.0	2.7	0.0	0.0	3.8	9.7	5.3	6.0	5.8	2.8	0.0	0.9
Pink clover	1.0	3.3	1.0	0.0	0.6	0.0	0.4	0.0	0.0	1.0	1.6	0.8	0.0	0.4	0.6	0.0	0.3
Trefoil	0.5	1.7	0.3	1.1	4.1	0.0	0.2	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.3	0.0	0.0
Timothy	5.0	16.5	3.3	23.5	38.0	25.1	18.6	55.1	13.5	20.2	7.8	43.2	21.2	20.5	14.8	7.8	10.6
Common fescue	4.0	13.2	19.6	3.1	0.3	5.4	5.9	16.0	46.4	0.3	1.4	17.4	3.2	1.2	18.8	1.6	2.7
Kentucky Bluegrass	2.0	6.6	0.0	8.1	2.2	10.8	7.8	1.3	1.6	0.3	6.9	2.3	8.8	12.7	6.2	9.1	7.6
Red fescue	1.0	3.3	0.7	4.6	1.6	2.0	1.8	1.0	0.0	0.6	4.1	4.5	12.9	7.7	0.0	6.6	4.2
Italian ryegrass	3.0	9.9	6.0	0.0	0.0	7.5	0.0	1.0	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0
Perennial ryegrass	2.0	6.6	8.0	5.4	6.6	21.4	14.1	5.6	2.6	20.2	11.3	4.5	15.2	13.1	16.0	1.9	11.5
Tall fescue	4.0	13.2	31.2	29.8	13.6	6.4	21.1	2.5	0.5	23.4	22.5	1.5	13.4	9.3	17.8	28.2	29.1
Chicory	0.3	1.0	0.3	0.0	0.3	0.7	0.4	0.4	0.5	0.0	0.2	3.0	0.9	2.3	0.3	0.6	0.6
Herbs			11.3	0.0	12.0	0.3	1.2	1.0	7.8	7.7	16.3	0.0	0.5	14.3	3.1	8.2	3.0
Total	30.3	100.	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 8. Botanical weight analysis results

Place	**Seeding rate**		Farm E	Farm C	Farm H	Farm D	Farm B	Farm E	Farm C	Farm H	Farm D	Farm B
Year	**kg/ha**	**%**	7/13/2020	7/24/2020	7/24/2020	9/9/2020	7/20/2020	8/23/2021	8/24/2021	8/24/2021	8/26/2021	8/10/2021
Alfalfa	2.5	8.25	4.9	3.14	2.20	3.50	2.42	15.18	8.12	20.09	16.86	30.05
White clover	2	6.60	7.2	14.45	13.40	48.38	6.88	8.83	33.63	13.18	7.23	5.18
Red clover	3	9.90	13.1	19.66	41.49	0.15	26.64	24.08	8.46	8.56	6.99	5.18
Pink clover	1	3.30	4.1	5.19	4.31	2.30	13.76	1.56	1.10	2.31	1.26	5.18
Trefoil	0.5	1.65	0.1	0.09	0.08	0.30	0.43	2.60	0.21	0.00	3.94	6.22
Timothy	5	16.50	17.7	6.24	1.76	11.50	2.82	16.48	8.04	15.55	14.22	2.59
Common fescue	4	13.20	13.3	3.53	1.56	2.20	4.87	3.63	3.81	4.94	1.42	2.59
Kentucky Bluegrass	2	6.60	0.6	0.18	0.10	0.44		1.56	0.76	2.24	0.45	0.00
Red fescue	1	3.30	2.1	0.59	0.39	0.25		1.23	0.42	2.31	0.89	0.00
Italian ryegrass	3	9.90	10.8	15.52	17.43	3.60		0.00	4.74	2.24	0.57	0.00
Perennial ryegrass	2	6.60	5.1	16.97	7.08	10.34	9.78	3.76	3.47	5.93	6.82	5.18
Tall fescue	4	13.20	7.7	5.90	1.54	1.36	19.39	9.73	18.65	14.49	6.42	27.46
Chicory	0.3	0.99	11.0	5.24	7.10	14.60	7.83	4.35	3.51	6.32	17.34	5.18
Herbs			2.3	3.29	1.55	1.10	5.18	7.01	5.08	1.84	15.60	5.18
Total	30.3	100	100.0	100.0	100.0	**100.0**	100.0	100.0	100.0	100.0	100.0	100.0

Feed value analysis

What was done

ETKI researchers performed a feed value analysis of the experimental grasslands for 5 participating farms over two years, being 2020 and 2021. In the third year of the project only data from one farm was collected given the researchers ran out of budget.

Before each grazing round, grass samples were taken with a 0.25 m² frame at a height of 5 cm from 4-8 places. Samples were taken depending on the topography of the experimental area, so that the samples would be representative for the entire experimental area in so far as possible. The samples were weighed, air-dried, and the dry matter content and nutritional value of the grass were determined using a generally accepted method in the ETKI laboratory.

Results

When analysing the forage in terms of quality the following threshold were used. For CP a percentage above 14% was considered good quality. In regards to ADF a value below 35% was considered good quality. NDF below 46% was considered good while NDF above 61% was considered as bad quality. For DDM a level above 65% was considered good quality. When assessing ME a value above 9.5 MJ/kg dry matter.

Following these thresholds, the feed quality of the biodiverse pasture mix scored very well in the first year, with all values indicating high quality, apart from two data points for DDM which were just below the threshold value in two farms during one grazing rotation. In the first year the amount of forage biomass increased after each grazing round, and declined again when plant growth slowed down near the end of August or beginning of September. CP level varied during the season, without any clear pattern. For ADF, NDF, DDM and ME the values in the beginning of the grazing season were highest, dropped during May, June and July, and picked back up again afterwards. This coincides with reduced rainfall and increased temperatures in spring and summer, which could potentially explain the drop in nutritional value. For farm A, data for one grazing cycle was not recorded seeing the farmer notified the researchers after he had grazed preventing them from collecting data.

In the second year the feed quality values declined significantly compared to the first year. CP and NDF remained in good quality throughout the season, ADF and ME were variable in quality across farms with only 1 farm having good quality all season long. In regards to DDM, values on all farms were mostly below the threshold, with only two data points indicating good quality. Similarly as in the previous year a forage biomass increases during the season and drops near the end, while a drop in nutritional values can be seen in May, June and July.

The decrease in values in 2021 can in part be explained due to the extreme heat during that year, combined with a large population of horseflies. In 2020, the weather conditions were favourable for the growth of forage species in all the test locations - the temperatures were high enough for good growth but also not too hot, while there was adequate rainfall and soil moisture. For the first round of grazing in 2021 there was adequate soil moisture due to the snowmelt water and the precipitation in May. However the following months stood out with exceptionally high air temperature and little precipitation in June and July. The maximum air temperature in Jõgeva rose above 25 °C on 39 days and above 30 °C on 11 days. Previous

research clearly shows that the uneven distribution of precipitation is an important influence on the yield of organic forage production. Additionally, 2021 had an extremely high population of horseflies which caused significant stress in the livestock. In stressed conditions cattle graze much less and thus have larger parts of the pasture become overrested causing a loss of nutritional value.

For the third year there is only data available from a single farm seeing that the allocated budget to the research partner ran out in 2022. This prevents further analysis. As such, there are only data points spanning 2 years, which cannot give any reliable indication of trend or direction, especially given the extreme weather of 2021.

When comparing the results with average production values in Estonia we can see that the yield levels during the experiment were mostly on the high end of the average yield values of 8-10 t/ha of dry matter of good cultivated grassland in Estonia. Even in the extreme conditions of 2021 this yield level was still achieved by some farms. The average yield of Estonian natural pastures sits at 1.5-4 t/ha of dry matter. However that level is not for continuous grazing and not for AMPG systems. In terms of yield data and grazing rounds, some farmers decided to also take one cut of silage, hence leading to lower grazing rounds.

Looking at the dry matter content of the forage on pastures, average levels in Estonia sit at 14-16%, and going up to 30-40% during a dry period in the growing season. The results in this experiment are generally in line with this average. When looking at the results of 2021, this indicator again shows the dry and hot conditions, seeing dry matter content was significantly higher in this year during June and July compared to the previous year.

In terms of CP, the average content sits at 20% during the rapid growth in spring. In this experiment only one farm managed to get those results in spring, while others got to this level near autumn. This shows that through AMPG grazing systems, it is possible to keep CP levels at a good level during the growing season.

When analysing ME of forage in Estonia, there is a wide variance reaching between 7-12 MJ/kg dry matter, with young pastures mostly around 10.5-12 MJ/kg dry matter and older pastures around 10 MJ/kg dry matter. Again the results are in line with these averages, with ME in 2020 sitting near the higher end of the average, and results in 2021 sitting mostly near the average in the beginning and end of the grazing season, but below the average in the middle. Again this can be attributed to the extreme weather.

Overall, these results show that pasture yield and nutritional value in the first two years of establishing a high diversity pasture that is being grazed with AMPG grazing systems are of good quality and remain of good quality throughout the grazing season. However, the timespan of 2 years is far too short of a timespan to make lasting conclusion. More research that builds on these results would be needed to fully understand the performance of this proposed species mix.

Table 9. First-year feed value analysis results

Farm E		Pasture yield t/ ha	DM, %	DM y t/ha	CP	ADF	NDF	DDM	ME
1	5/22/2020	3.42	14.8	0.51	15.6	16.0	29.9	76.4	11.8
2	6/17/2020	11.65	15.7	1.82	20.6	25.1	41.1	69.3	10.7
3	7/13/2020	12.65	24.0	3.03	20.8	22.2	25.1	71.6	11.1
4	8/19/2020	16.64	20.6	3.43	18.0	24.4	26.8	69.9	10.8
5	10/16/2020	5.39	26.4	1.43	20.6	18.6	20.0	74.4	11.5
Farm A									
1	5/19/2020	3.6	21.9	0.79	14.6	16.3	30.7	76.2	11.8
2	6/??/2020	/	/	/	/	/	/	/	/
3	7/24/2020	7.6	37.4	2.84	16.0	27.1	30.4	67.8	10.5
4	8/27/2020	19.88	19.3	3.83	18.5	22.8	25.2	71.1	11.0
Farm H									
1	5/19/2020	3.85	21.1	0.81	16.3	18.2	29.7	74.7	11.6
2	7/24/2020	17.65	24.7	4.36	16.8	26.3	29.5	68.4	10.6
3	8/27/2020	3.59	21.9	0.79	25.1	17.4	20.2	75.3	11.7
Farm D									
3	5/22/2020	2.9	22.1	0.64	15.3	15.2	28.6	77.1	11.9
3	7/23/2020	12.6	36.1	4.54	10.6	34.8	39.6	61.8	9.6
3	9/9/2020	/	32.6	1.63	23.6	17.1	18.9	75.6	11.7
Farm B									
1	5/19/2020	6.0	24	1.44	12.0	17.3	31.4	75.4	11.7
2	6/29/2020	11.3	29.7	3.3	15.8	28.0	43.9	67.1	10.4
3	7/20/2020	15.1	35.9	5.4	13.6	31.5	49.2	64.4	10.0
4	9/9/2020	4.5	23.0	1.0	20.3	26.9	38.0	68.0	10.5

Table 10. Second-year feed value analysis results

Farm E		Pasture yield t/ ha	DM, %	DM y t/ha	CP %	ADF %	NDF %	DDM %	ME MJ/kg dry m
1	5/31/2021	10.7	26.68	2.57	17.5	33.2	38.9	63.0	9.8
2	6/21/2021	16.3	28.84	4.32	17.0	44.2	49.2	54.5	8.4
3	7/21/2021	5.5	39.82	2.09	12.7	56.9	59.4	44.5	6.9
4	8/23/2021	5.1	16.33	0.74	24.8	41.2	44.1	56.8	8.8
5	10/9/2021	2.1	24.01	0.48	21.7	32.2	36.5	63.8	9.9
Farm A									
1	6/1/2021	12.3	23.3	2.60	16.1	36.1	42.7	60.8	9.4
2	6/25/2021	9.15	19.2	1.64	20.7	43.4	46.8	55.1	8.5
3	8/24/2021	9.45	19.6	1.76	18.7	40.3	42.2	57.5	8.9
Farm H									
1	6/1/2021	9.45	26.0	2.24	18.9	28.8	36.0	66.5	10.3
2	6/25/2021								
3	8/24/2021	7.5	26.11	1.96	19.8	37.3	43.0	59.8	9.3
Farm D									
1	6/3/2021	7.95	29.72	2.20	17.5	33.3	40.3	63.0	9.8
2	8/26/2021	8.85	14.76	1.21	24.4	44.7	49.9	54.1	8.4
3	10/11/2021	9.45	41.59	1.88	17.7	38.3	44.8	59.1	9.2
Farm B									
1	6/7/2021	18.8	24.8	4.66	13.4	32.0	32.7	63.9	9.9
2	8/10/2021	8.6	31.8	2.73	16.2	32.3	35.7	63.7	9.9
3	10/15/2021	7.5	28.6	2.15	16.2	27.5	31.5	67.5	10.5

Conclusion

The results of the analysis are to be expected seeing that every farm has a different micro-climate and different soils, and thus different results. As such, it is very unlikely that one specific seed mixture will perform well in all pastures. Nature is far too complex to have so-called silver bullet solutions that work everywhere. Rather, all farming practices have to be tailored to the specific conditions and context of each farm and field.

This does not mean that there is no benefit to designing biodiverse seed mixtures. The diversity in the seed mixtures is not there to provide the same results across every farm. Rather, it is there to ensure that within the seed mixtures there is enough diversity that for every type of field there are at least some high quality forage species that will perform well. As such, a standard diverse seed mixture is a good solution when farmers don't know which species would perform well in their pastures and want to have a broad spectrum solution that will perform. If farmers are more informed about their pasture conditions and soil properties, it would be better for them to select their field specific diverse species mix that works well for their specific pastures, and as such save money by not planting seeds that anyway would not work well.

This however requires an in-depth understanding of the interactions between plant species and varying soils and soil conditions. This knowledge is lacking in most farmers, both in terms of plant species and in terms of understanding their soils. Future solutions aimed at lowering the threshold of adoption of biodiverse pastures and their benefits, should recognise the need for pasture specific solutions, and accommodate for the lack of knowledge on the subject by farmers.

Additionally, the lessons learned from this project in regards to research methodologies and timeframe should be taken into account in future projects. A 2-3 year time frame is too short to provide any meaningful insights into pasture performance and species composition. Rather a minimum period of 5 years of monitoring should be performed. This is informed by the Ecological Outcome Verification (EOV) methodology. This is a framework developed by the Savory Institute from the US, in collaboration with leading universities and experts across the world, to monitor the performance and biodiversity in pastures. At present, there are no institutes or organisations offering EOV monitoring in Estonia. The research activities in this project were outsourced to leading Estonian research institutes. In general there seems to be a lack of knowledge in Estonia in regards to grazing, which can also be seen in the lack of Estonian literature on grazing systems or grazing research trials. The most recent literature was written in the period of 1960-70.

Appendix 1: Summary of literature review of grass seed mixtures for beef cattle

Pasture-based beef cattle farming

Summer feeding

In pasture-based beef cattle farming cattle are kept on pasture for more than half of the year, utilizing permanent grasslands (PR) located in fields and semi-natural communities of natural grasslands in dry pastures, beach pastures, and meadows. Grazing beef usually grow well in spring and early summer when the nutritional value is high, but slower in mid-summer and autumn. This can lead to variation in beef quality and longer turnover time.

Maintaining pastures by mowing, harrowing, and using paddock or rotational grazing can improve grass quality in the autumn. Areas previously used for silage or hay can also be used as fall pastures. Pasture grass can cause diarrhea in cattle, especially in spring and approaching autumn, but this is less of an issue in areas with lower nutritional value grass. Grazing typically ends in September or October.

Properly organized grazing can keep grass in a constant sprouting phase with low fiber and sufficient energy and protein content. Young beef cattle (Aberdeen Angus and Hereford) can grow 600-850g/day with enough grass. Lactating cows consume 45-60kg of grass per day on pasture, covering their basic nutritional needs with medium-value grass. Pasture manure spreading requires high-value grass species and good maintenance for optimal grass cover.

Grass species can be evaluated based on their nutritional value, with high-value species including white clover, alfalfa, red clover, ryegrass, and bluegrass. Good-value species include alsike clover, timothy, meadow fescue, soft-leaved tall fescue, red fescue and Alaska brome, while medium-value species include brome grass, reed canary grass, cock’s foot, meadow foxtail and bentgrass. Grasslands typically contain mixtures of several species, with higher-value species having shorter lifecycles and being replaced by less valuable species over time. Troublesome grassy weeds, such as dandelions and buttercups, can also spread. Semi-natural plants remain established for years with average yield value.

Winter feeding

For winter feed, optimal systems of growing and harvesting fodder crops can ensure that grass fodder meets the nutritional requirements of animals by providing the necessary energy density. The digestibility of organic matter in grass fodder is closely linked to the fibrous fraction of carbohydrates, and this determines the dry matter metabolic energy content. The younger the grass plants, the less fiber they contain, and the structure of grass fodder plays an important role in its nutritional value. Silage and hay were cut multiple times during the growing season to produce grass fodder with high nutritional value. On average, pasture grass has the highest metabolizable energy content at 10 MJ kg-1, while

silage and hay have lower levels at 9 MJ kg-1 and 8 MJ kg-1, respectively. Protein content is highest in pasture grass and lowest in hay.

The nutritional value of grass fodder is influenced by the species, variety, and growth stage of the plants. The quality of the forage decreases as the growing season progresses but selecting appropriate varieties and species can extend the optimal harvesting time. Seedling renewal technologies are used to maintain the productivity of permanent grasslands. Permanent grasslands that have been in use for a long time, unfertilized and poorly maintained need a more thorough renewal.

The nutritional value of grass forage has a significant impact on the production results of beef cattle when fed ad libitum, and this can be evaluated based on food intake, dry matter digestibility, and metabolic energy. When preparing the ration for feeding grass silage in the barn or feeding area, the energy consumption calculated according to the daily mass gain should be taken with at least a 10% overlay. The younger the animals, the more nutritious grass feed they require for weight gain (see Table 1).

Table 1. Efficiency of grass fodder with different nutritional value

Feed	ME/MJ kg	Animal intake, % liveweight	Growth g/day, live weight	
			300 kg	500 kg
Pasture grass: - high nutritional value - good nutritional value	 11,0 9,0	 3,0 2,5	 1500 800	 1800 1100
Silage: - good nutritional value - medium nutritional value	 10,0 8,5	 2,5 2,0	 700 500	 800 700
Hay: - average nutritional value	 8,0	 2,0	 400	 600

Grass fodder (pasture grass, silage, hay) is known to provide young animals with an average gain of up to 1000 g/day. Additional concentrate is needed for higher gains. Breed plays a significant role in the increase of live weight, with different breeds producing varying results in the same pasture. Charolais and Simmental breeds showed better growth compared to Hereford, and Charolais showed better slaughter results than Simmental at the same live weight.

Why use species-rich grasslands?

Advantages of species-rich grassland include[1]:

- Extends the grazing period, because the growth maxima of different plant species follow from spring to autumn. Mixing cold season and warm season species is crucial in this regard.
- Fixation of atmospheric nitrogen – leguminous plants fix atmospheric nitrogen in the soil, which can be used by other species.
- Deep-rooted plants bring minerals such as calcium, magnesium and iron into the upper soil layers where they are used by other species.
- Deep-rooted herbs and grasses (e.g. alfalfa, tall fescue) are fodder for animals in the dry season.
- The root system of deep-rooted plants penetrates the compacted soil layer and increases the content of soil organic matter.
- Legumes, grasses and herbs growing on the species-rich grassland ensure the economic success of the cattle breeder. Key drivers for this are increased pasture productivity and a broader nutritional profile of the pasture which increases cattle performance.

Research and experiments on different pasture mixes

Finland

In Finland, grassland usually consists only of a mixture of timothy and meadow fescue. These species are the most resistant to the harsh Finnish winter and deep snow, but also to the hot summer and intensive management. Usually, the productivity of such grasslands is 5 t of dry matter per hectare (KA/ha).

To improve the productivity, an English seed mixture has been tested in Finland. This mixture consists of 55% timothy, 15% tall fescue, 15% meadow fescue, 15% pasture ryegrass, and 4-5 kg of a mixture of white, red and alsike clover. The results of testing this mixture were very positive both in terms of pasture coverage and KA yield (10 t/ha).

Another seed mixture suggested for beef cattle pastures, developed by a Finnish company Naturcom Oy, consist of 33% timothy Grindstad, 15 % meadow fescue Kasper, 8 % pasture ryegrass SW Birger, 7 % pasture ryegrass Mathilde, 10% bluegrass Bali, 10 % tall fescue Retu/Swaj, 5% red fescue Gondolin, 5% white clover Jõgeva 4/SW Hebe treated with bacteria, 5% alsike clover treated with Frida bacteria, 2 % red clover SW Yngve/Bjursele/Rozeta treated with bacteria.

European herbalists have also studied common sainfoin (*Onobrychis viciifolia Scop*) and bird's-foot trefoil (*Lotus corniculatus L.*) addition to grass mixtures and their effect on livestock health. In summary, the benefits of having a 30-50% leguminous share in grassland plants are increased yields, addition of atmospheric nitrogen to the soil, higher feed intake and better nutritional value for beef cattle, faster weight gain of animals, and improved animal health due to the presence of tannins in plants such as common sainfoin and bird's-foot trefoil. Nitrogen bound by leguminous plants also fertilizes other grassland plants.

Canada

Canadian researchers studied 54 pasture plant communities and recommended 5 grass seeds based on the results.

The mixtures proved to be resistant to changing weather conditions and had a higher feed value than pure-species/minor-species seedlings. The composition of the mixtures has an effect on the development and growth rate of beef cattle. The composition of the best seed mixtures included: alfalfa, bird's-foot trefoil, timothy and cock's foot – unfortunately, the exact composition of the seed mixtures was not published.

Denmark

Danish scientists have emphasized the species richness of grasslands[2]. Species sown in the experiments included pasture ryegrass, common ryegrass, white clover, red clover, alfalfa, bird's-foot trefoil, chicory, ribwort plantain, caraway, salad burnet, chervil and common sainfoin. The results showed that species-rich grasslands are more productive compared to three-species grasslands. Species-rich grasslands had higher yields and were more durable, especially when alfalfa was also in the mix. The species-rich grassland also had fewer weeds. Continuous grazing or mowing reduced productivity in all species.

Based on the experiments, it seems important to balance dominant species with non-dominant ones. The sowing rate of different species takes complex optimization in the mixture, to ensure the production of stable and high nutritional value feed.

Table 2. Test conducted in Denmark with different multi-species mixtures

	Species		Sort	Weight of 1000 seeds (g)	3-mix	10-mix	12-mix
					kg ha^{-1}		
Grasses	Pasture ryegrass	*Lolium perenne L.*	1)	2,7	21,3	17,2	7,4
	Common ryegrass	*Festulolium braunii K.A.*	Perun	3,7			8
Legumes	White clover	*Trifolium repens L.*		0,7	3,7	3	1,3
	Red clover	*Trifolium pratense L.*	Rajah	1,8	1	0,8	0,3
	Alfalfa	*Medicago sativa L.*	Pondus	2,1			4
	Bird's-foot trefoil	*Lotus comiculatus L.*	Lotanova	1,1		0,5	0,5
	Common sainfoin	*Onobrychis viciifolia Scop.*	3)	17,3		0,8	0,8
Herbs	Chicory	*Cichorium intybus L.*	Spadona	1,5		0,7	0,7
	Ribwort plantain	*Plantago lanceolata L.*	2)	1,6		0,8	0,8
	Caraway	*Carum Carvi L.*	Sylvia	2,9		0,8	0,8
	Salad burnet	*Sanguisorba minor Scop.*	3)	5,3		0,8	0,8
	Chervil	*Anthriscus cerefolium L.*	3)	2,2		0,6	0,6

1) A mixture of pasture ryegrass and white clover sold in Denmark (85% pasture ryegrass, of which 30% mid-maturing tetraploid, 27% late diploid and 28% late tetraploid variety; 15% white clover - 11% large-leaf and 4% medium-leaf variety)
2) Wild (natural) form
3) The name of the variety is not included

USA

Experiments conducted at University of Utah with bird's-foot trefoil showed particularly high nutritional value of the feed – low fiber and high energy content[3]. The low content of tannins in bird's-foot trefoil contributes to better utilization of proteins. The results show

that it is possible to fatten beef cattle on grasslands with high nutritional value in one season.

The beef finished with bird's-foot trefoil produced more tender and juicy meat compared to the concentrate-based feed. The ratio of Omega-6 to Omega-3 fatty acids in the meat of cattle grazed on grasslands was similar (in the range of 2-3, healthy is < 4), while the corresponding ratio was 6-15 in the meat of animals fed with concentrate.

Bird's-foot trefoil reduces the number of parasites and their ability to infect animals, as well as reducing methane and ammonia emissions. It also increases animal growth because the proteins contained in it are broken down more slowly and more completely. The plant has a higher concentration of non-fibrous carbohydrates compared to alfalfa, so the ratio of protein to carbohydrates is more equal, which ensures better digestibility.

New Zealand

Researchers in New Zealand have found that a mixture of herbs and legumes encourages cows and sheep to eat more of the more nutritious grass compared to pasture ryegrass[4]. The digestibility and metabolizable energy content of the herb and legume mixture is higher and the neutral fiber content is lower than pasture ryegrass. Sheep gained 70% more weight when they were fed grass that also contained chicory, ribworth plantain, red and white clover compared to sheep fed only pasture ryegrass.

Table 3. Relative feed values of different species based on live weight gain of sheep when the value of white clover is 100

Species	**Value**
White clover	100
Chicory	95
Bird's-foot trefoil	87
Big trefoil	84
Tetraploid Italian ryegrass	83
Alfalfa	82
Red clover	70

Timothy	67
Pasture ryegrass	52
Common bent	46

Grassland where chicory, ribworth plantain, red clover and white clover grow together show seasonally more uniform growth as compared to these species growing separately. It is often believed that pastures rich with pasture ryegrass and white clover should be renewed every 10 years, but studies have shown a decrease in their yields already after 3-5 years[1].

[1] Sanderson & Webster (2009) *Economic analysis of the value of pasture to the New Zealand economy*. Report to Pasture Renewal Charitable Trust. Wellington: BERL, 2009. p.42.

[1] Summary based on field trials at Aberystwyth and Bangor University (UK)
[2] Jing et al. (2017) *Species Diversity Effects on Productivity, Persistence and Quality of Multispecies Swards in a Four-Year Experiment* https://doi.org/10.1371/journal.pone.0169208
[3] MacAdam & Griggs (2013) *Irrigated birdsfoot trefoil variety trial: Forage nutritive value* https://digitalcommons.usu.edu/extension_curall/1336/
[4] Kemp et al. (2010) *The use of legume and herb forage species to create high performance pastures for sheep and cattle grazing systems* https://doi.org/10.1590/S1516-35982010001300019

Appendix 2: Informational material for farmers on silage and hay

Silage

Silage acidity

Silage pH should be considered along with dry matter when evaluating its quality. A lower pH indicates more acidity, which is necessary to inhibit the growth of undesirable bacteria in wet silage (dry matter content < 25%). However, when ensiling drier material (dry matter content > 35%), a higher pH may not necessarily indicate poor quality, but such silage may be less stable when exposed to air. The use of biological additives can also affect silage pH. Legume silage tends to have a higher pH and lasts longer. A more accurate assessment of silage quality can be made by looking at the entire profile of fermentation indicators.

The optimal pH levels are:

Dry matter wet silage <25%	pH 4.1...4.3
Dry matter 25 to 40%	pH 4.3...4.7
Dry matter 40...55%	pH 4.7...5.0

During the collection of samples, there was no doubt about any silage (bad smell of silage, color, mold, high temperature etc.), therefore additional study to the concentration of different acids none silo case there is no need. The general impression of the quality of the silos in visual and organoleptic evaluation was very good. In the studied silos, the pH was mostly slightly above 5.0.

Crude protein (TP %)

The protein content of feed includes nitrogen-containing compounds from proteins and nitrogen-containing non-protein compounds. The protein content together with the fiber provides an indication of the growth phase when the grass was harvested, and the increase in the percentage of ADF (acidic fiber) is the best indicator for silage analysis. Silage made from leguminous grasses in the early growth phase can have high protein content, but it can quickly break down into ammonia in the cattle's rumen, causing health problems. A balanced ratio of protein and energy in the rumen is important for good nutrient absorption and higher production. Silage with TP 11-14% is enough for a lactating cow, while the highest protein and energy silage is suitable for fattening animals to achieve higher growth rates and well-developed muscles.

Acid fibers (ADF %)

ADF is an indicator of the digestibility of grass and basic fodder, with lower percentages indicating better quality. ADF levels increase as the plant ages and lignin content rises, making the feed less digestible. Good silage has ADF levels below 35% for legumes and below 37% for grasses. Late harvesting in grasses results in poor fermentation and lower nutritional value due to high fiber content, leading to poor digestibility and reduced feed intake.

Net neutral fiber (NDF %)

NDF is a measure of the plant cell shell substances and is related to feed intake because it contains all slowly digestable or indigestible feed ingredients. NDF below 46% is considered good, while NDF above 61% is bad. Leguminous plants should have NDF below 46%, while grasses should have NDF below 55%. The less NDF in the feed, the more the animals can eat. Fast-growing fattening and young animals need well-digested grass feed.

Digestive dry matter content (DDM %)

Feed nutrients are not fully usable by animals, and only a part is digested and absorbed in the alimentary canal, while the rest is ejected as feces, which is the indigestible part of feed. The digestion coefficient shows how much of the feed nutrient is digested, and it can be expressed for dry matter, each nutrient, and organic matter of the entire feed. The higher the digestibility coefficient, the more valuable the feed is. The digestibility of feeds and nutrients depends on animal and feed-related factors. Very good organic matter digestibility is more than 65%.

Dry matter food (DMI %) to create per body weight

The potential feed intake of an animal is affected by factors such as the composition of the ration, silage fermentation products, and digestibility. An example of this would be where an analysis shows that a silo has a dry matter content of 40% and the animal's dry matter intake (DMI) is 2% of its body weight. For a bull weighing 500 kg, its maximum DMI from the silo would be 10 kg. This means that the bull could consume up to 25 kg of the silo per day based on its body weight (100 * 10/40 = 25 kg).

Relative feed value (RFV %)

The value given provides an estimate of the relative feed value. A value over 100 indicates a better feed value and quality. It is good to give grass feed with a higher value with a lactating cow and is suitable for young animals that require rapid growth and development.

Metabolizable energy ME MJ/ kg dry matter

The quality of grass feed is indicated by the relative feed value, and the energy content depends on the digestible nutrients and the harvesting time. Late-harvested grass has higher ADF and more energy. Stocked grass silage may have similar chemical composition to cultivated grassland, but the digestibility may be worse due to smaller particle size. A good silage should have an ME content of more than 9.5 MJ, which is necessary for fattening animals and lactating cows.

Starch + sugars %

To ensure faster growth and muscle development in fattening animals, it is important to have grass feed with a higher metabolizable energy content, which is achieved through a higher starch and sugar content. However, in final fattening rations with a lot of concentrate, it is important to consider the indicators of starch and sugars to prevent an increase in rumen acidity and rumen acidosis.

Hay

Harvesting & drying

Hay quality depends on several factors, including botanical composition, growth phase at harvest time, fertilization, soil, weather, and storage conditions. The best time to harvest hay is from establishment to the beginning of flowering. Meadow plants rich in grasses provide valuable grass fodder only in the early season when harvested in the development phase. The optimal mowing time is determined by the growth and development of the dominant species. Legumes such as white clover, alfalfa, red clover, and ryegrass have a high nutritional value. Fertilizing can accelerate the growth of grass and increase yield, but the main indicators of nutritional value remain dependent on the species composition and length of the growing season before harvesting.

Hay is often harvested late due to weather conditions, leading to decreased nutritional value. Drying of mowed grass is affected by precipitation, air humidity, temperature, duration of sunshine, and wind speed. Good drying conditions are when humidity drops to 51-60% during the day, mostly on dry days. Hay can be stored if humidity remains below 70% throughout the day. The color of hay depends on the species and soil conditions. High-quality hay should contain at least 10% protein and 9.0 MJ/kg of metabolizable energy in dry matter.

Moisture & colour

Hay is evaluated for moisture content by breaking and twisting it between hands. Dry hay has a moisture content of ≤15% and feels rough and rustles. Average dry hay (17%) feels soft and cooler, and plant stems do not break as easily. Moist hay (17-20%) does not rustle, and the plant stems do not break even when bent repeatedly, and wet hay (20-23%) feels cold and has visible moisture. Hay must not exceed 15% moisture to prevent mold. Different

types of hay can be evaluated separately and stored accordingly to feed animals with higher nutrient requirements during winter.

The color and nutritional value of hay can change depending on how it was harvested and stored. Hay harvested in good weather has an aromatic smell and a greenish color, while hay that has been exposed to heavy rain or moisture can turn yellow, brown, or black and lose its nutritional value. Damp hay can also develop mold and a musty smell, which can cause it to become dusty.

Nutritional value

Using legumes in organic farming can increase yields and soil fertility and improve nutritional value. However, if grasslands are not established by sowing, the feed may remain with a low nutritional value. The main drawback of hay is its low nutritional value, mostly 8 MJ in practice, and the older the vegetation, the worse it digests.

Hay should be kept in a barn or shelter to prevent it from absorbing moisture from the air and ground. If kept uncovered, mold growth can reduce the feed value of hay by 20-30%, harming animals that consume it. Pregnant cows and heifers are especially sensitive to mold toxins that can cause health problems. When using hay as the only staple food, it's important to consider the energy and protein needs of the animals, especially for young animals that are still growing and developing.

Calves need high-quality protein supplements if they are not getting enough from their mother's milk by six months of age. Young animals need grass feed with high energy and protein content. Late growth phase hay is not suitable as the main feed for fast-growing young animals. Fattening animals need at least 10.5 MJ/kg of dry matter and 14% protein to grow quickly. Pregnant cows can get their nutrients from modest hay or silage, but need better feed at the end of pregnancy and during lactation. Adding cereal flour or concentrated feed is necessary when feeding only low-nutritional-value hay.