INTRODUCTION

At the present time fodder galega (*Galega orientalis* Lam.) is a well-known new fodder crop in Estonia, which has found a certain place among other legume fodder crops. It has a stable growing area and it is approved by farmers.

On the recent years fodder galega has earned a big attention of scientists and agricultural specialists from the areas of former Soviet Union, Europe, USA, Canada and Japan. But the information about galega available in the world is rather dispersed and one cannot get an entire picture about it. Considering the fact that the plant was first introduced at the Estonian Research Institute of Agriculture in 1970ies and these studies are until now, due to a lot of experience, the basic material for researchers and practicians studying galega, the need for recording this collective scientific work has come actual.

The present monograph summarises the scientific research studies made with fodder galega in Estonia. Multidisciplinary approach in galega studies has enabled to create a database about galega`s introduction, its biology, agrotechnology, feeding value, seed growing and breeding. The studies in this field have mainly been carried out at the Estonian Research Institute of Agriculture, under supervision of D. Sc Helmut Raig. The researchers Ph.D Heli Nõmmsalu and Ph.D Jelena Metlitskaja and agronomist Heli Meripõld have worked in the main staff of the research group. Ph.D Peeter Viil, Ph.D Uno Tamm, Ph.D Riho-Jaak Sarand, Helgi Laitamm, D.Sc Paul Lättemäe and some others from the same Institute have also participated in galega studies. The researchers from the Institute of Grassland Science and Botany of Estonian Agricultural University Ph.D Rein Viiralt, M.Sc Toomas Laidna and others have carried out investigations with galega, too.

The approval and support of specialists working in agriculture have had a positive effect on galega`s popularity in Estonia. Their extensive attention has especially been earned by a lot of experience received from plant's agrotechnology when growing it as a fodder crop and also at recultivating it on less fertile soils for increasing the soil fertility.

Proceeding from the novelty of the research work made with fodder galega, the Committee of Discoveries and Inventions of the former Soviet Union granted a patent to galega investigators which deals with galega nodule bacteria preparation. The preparation contains the certain stem of the bacteria *Rhizobium galegae*, separated in Estonia and is being used in galega`s agrotechnology even now. In 1988 just before re-emancipation the State Agro-industrial Committee of the Soviet Union issued a patent to Estonian scientists on galega`s first variety Gale. For presenting the new fodder crop galega and for introducing it into production, the supervisor of this research work Dr H. Raig was awarded a State Prize by the Government of the former Soviet Union in 1984.

The galega field attracts the attention of both people and bees with its beautiful bright lilac flowers already from a distance. Bees and bumblebees and other insects often visit the plants to gather pollen and suck nectar. So galega is a valuable honey plant but also a beautiful decorative plant for growing in a home garden. It surprises us with its indulgence. Many stony slopes turn beautiful and fertile due to growing galega. Galega fields are favourite places for goats. They give the spectator of an unforgettable picture when jumping over plant tops.

1. THE HISTORY OF ADAPTATION AND INTRODUCTION OF FODDER GALEGA

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1.1. Early researches of fodder galega

In the history of almost all civilised countries, there are periods which are characterised by an intensive interest towards the introduction and acclimatisation of natural plant species and populations. But very often these periods were short and disappointing from the aspect of introduction or utilisation possibilities of one or another natural plant. Thus, after some time scientists turned back to already tested plants or gathered new species and genotypes of natural flora and studied them with modern scientific methods.

In the present situation, the production of resistant and persistent leguminous fodder crops for agriculture may become of the utmost importance.

It is important to note that only 5000 out of 250 000 angiosperm species were domesticated and only 150-200 species are widely used. Even among these cultured plants only 20-30 species have a really broad using (Zhucheno, 1999). The usefulness of fodder crops is determined not only by the necessity of fodder production, but also by soil conservation and environment protection.

Among the new crops fodder galega (*Galega orientalis* Lam.) is higly important. It is characterised by high yields of herbage, intensive symbiotic nitrogen fixation, preservation and formation of a healthy soil microflora.

The English name of genus *Galega* is goat's rue. Unfortunately, under that name it is not possible to differentiate the growing and utilisation possibilities of two known species of genus *Galega*: fodder galega – *Galega orientalis* Lam. and *Galega officinalis* L., which is an ornamental and medicinal plant. "ISTA list of Stabilised Plant Names" published by the International Seed Testing Association in 1988 included *G. officinalis* L. under ornamentals, herbs and medicinal plants, but *G. orientalis* Lam. which is a less known field and fodder crop was not on that list.

Based on twenty years of experience with this new crop, the Estonian Research Institute of Agriculture made in 1993 a proposal to ISTA to include *G. orientalis* into the list of field and fodder crops under the specific name of fodder galega (Nõmmsalu et al., 1996). In substance this name corresponds to the purpose of use of the crop, and it avoids all kinds of misunderstandings and confusions with the toxic *G. officinalis.*

The studies of fodder value of genus *Galega* started from a *G. officinalis*. Now *G. officinalis* widely distributed in the nature in Central Europe on Caucasus and in Middle-East. There is a theory that into the countries of Central Europe the plant is brought during commodity exchange from countries of Middle-East and hereinafter it was spread to South America, New Zealand, Northern Africa and Southern Asia (Hegi, 1924; Varis, 1986; Grossgeim, 1930).

The first cultivation experience with *G. officinalis* was conducted in the year of 1600 in Germany. The interest was represented first of all by its medicinal properties. In 1773 F. Krause paid attention to the fodder value of *G. officinalis* and he proposed to grow it in culture (Raig, 1988).

At the end of the 19th century the analysis of gained experience of cultivating *G. officinalis* in France, Germany and Poland was conducted (Golov, 1873; Kalinski, 1873).

It is now established that *Galega officinalis* contains specific compounds such as alkaloids – the guanidine derivatives galegine and 4-hydroxygalegine and the chinazolin-type alkaloid vasicine, which are bitter-tasting and poisonous, and therefore it cannot be used as fodder plant (Schröck, 1941; Schreiber et al., 1964; Barthel, Reuter, 1968; Schäfer, Stein, 1969; Laakso et al., 1990).

Galega orientalis Lam. is more profitable because it does not contain alkaloids or contains them only by steps and can´t be toxic (Nõmmsalu, 1993; Varis, 1986).

Fodder galega as a fodder plant was not known in the countries of Western Europe in the 19th century and so not tested as a crop.

This plant is mainly growing in the area of the Caucasian mountains – in subalpine and in forest belts. There can be find also the districts of joint propagation of both species from genus *Galega – G.orientalis* Lam*.* and *G. officinalis* L. (Figure 1).

For the first time fodder galega was described in the natural habitat in 1908 by H. A. Rollov and he stressed fodder value of this endemic plant (Rollov, 1908). The scientist specified that fodder galega (*G.orientalis*) as against *G. officinalis* had a good edibility.

1.2. Cropping experiments and adaptation of fodder galega

The high estimation of this plant by its fodder value was one of the reasons why it was involved in the studies for using it in field conditions.

Cropping experiments started in Moscow district of Russia in 1920-1930s (Simonov, 1938; Raig, 1988). An extensive and long-term (1931...1970) introduction and selection of galega's natural populations in the Moscow district has been carried out at the former All-Union Institute of Fodder Crops by scientists S. Simonov and Z. Jartijeva. On expeditions to the Caucasus and Armenia the scientists of the above-mentioned institute gathered a lot of natural populations and hybrids. They were compared according to the morphological and biological properties and selected in order to get a more even ecotype of galega.

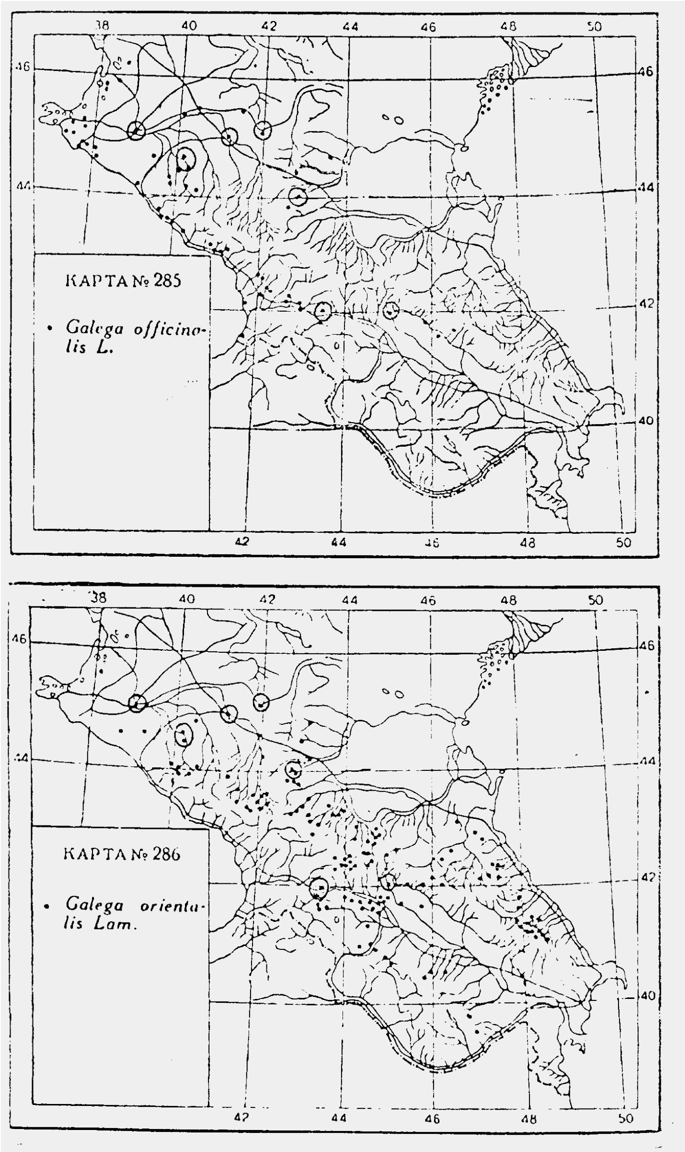

Figure 1. *The natural growing areas of G. orientalis and G. officinalis in the Caucasus (the areas where the both species are growing together are marked with circle). According to Grossgeim, 1930*

In the beginning of 1960s fodder galega was studied on Ukraine (Harkevitš, 1966).

We characterise the studies of fodder galega at 1920-70s as a stage of primary introduction or domestification. In this period the seed material gathered from natural growing areas was used.

Unfortunately, all results of these researches were not put into practice.

In the beginning of 1970s Dr H. Raig obtained galega seeds from the All-Union Institute of Fodder Crops and from All-Union Institute of Plant Production in Sankt-Petersburg, where was a collection of seeds from different parts of the Soviet Union, and an intensive research was started at the Estonian Research Institute of Agriculture.

As a result of mass and individual selection, winterhardy and drought resistant populations were picked out, suitability for mechanised harvesting, lodging resistance and falling resistance of seeds were studied. The agrobiology and agrotehnology for growing the new fodder plant on Estonian soils were also studied, as well as the nutritive value of galega in relation to its cutting time. The given research was carried out at the department of introduction of new fodder crops. The head of the research group was Dr Agr. prof. Helmut Raig. Ph.D. Heli Nõmmsalu and Ph.D. Jelena Metlitskaja worked as researchers, Heli Meripõld as an agronomist. A lot of more researchers from the Institute of Agriculture and other research establishments of Estonia participated also in scientific research of the given plant.

Since 1972 mainly the following problems have been studied:

- agrobiology, possibilities of growing galega for fodder and for seed;
- agrotechnology, pure sowings of galega and mixtures with grasses;
- nutritive value, biochemical composition and use;
- plant breeding and varietal improvement;
- galega as an improver of soil fertility and inhibitor of soil erosion.

The scientific evaluation by Swedish experts was given to this work carried out with a new fodder plant by the above-mentioned research group in the beginning of 1990s. This research project was highly estimated as a unique one and it should be definitely continued with this project due to its interesting potential. It usually takes time to get a new crop introduced and adapted to the different agroecological conditions and uses and Estonian researchers have done this work very successfully.

Estonian farmers met the new fodder crop with interest and approval.

The first seed fields of galega were established in 1976 at the experimental farms of Estonian Research Institute of Agriculture. Galega started to spread into production in 1980. The area under galega fields reached up to 100 hectares in the Estonian collective farms.

Together with re-establishing the independence of the Estonian Republic, in the course of agricultural reform the land was restored to formers owners and many of galega fields got farmers for their new owners. These galega fields produce valuable silage or hay up to the present. Farmers have also enlarged sowing areas of galega and keep it as a supplementary fodder crop among other legumes.

Galega fields have spread all over Estonia and arable land under fodder galega in the republic now reach up to 5000-6000 hectares (Figure 2). The area of galega fields in the farms is on the average 20-30 hectares.

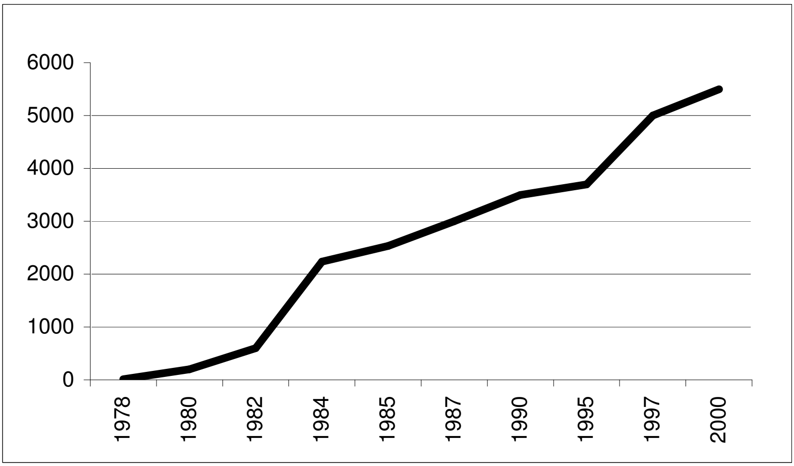

Figure 2. *Arable land (ha) under fodder galega in Estonia*

In one farm in Estonia for example a silage has been made on a 10 hectare galega field for several years running. The quality indicators of this silage are good. This silage contains usually 17.7% of crude protein and 27.8% of crude fibre per DM, silage pH is 4.5 and digestibility of organic matter is 62%. The average milk production in this farm is 8500-9000 kg per year.

The Estonian Research Institute of Agriculture and several Estonian agricultural enterprises have also grown galega seed for export. 4 tons of galega seeds have been sold from Estonia to Canada, the province of Quebeck. 50 kg of galega seeds have been bought by French farmers, 20 kg has been sent to Germany and over 400 kg have been bought by Finnish farmers during the last years.

1.3. Introduction of fodder galega

The first high-productive fodder galega variety Gale has been bred in cooperation between the scientists of the Estonian Research Institute of Agriculture and the former All-Union Institute of Fodder Crops (Moscow district) in 1987.

Variety Gale has many positive qualities: it has high yields, good winterhardiness, good drought tolerance and a stable seed production. Gale is economical and persistent and has a fast regrowth after cutting.

In the end of the 1980s and in the 1990s the seeds of the variety were distributed throughout Estonia, mainly into the northern and north-western part of the former Soviet Union, into the Baltic States and Scandinavian countries.

Possibility for obtaining seed production and propagation of certified seeds enabled in large amounts to extend the acreage under galega on the territory of the former Soviet Union (Figure 3).

The interest towards galega production was the greatest in the northern areas of the former Soviet Union, where the share of leguminous fodder crops was small and there was always a shortage of protein-rich fodder. The northern part of the zone between 40° and 60° of north latitude covers the regions of Volga-Vjatka, the Urals, Siberia and Far-East, as well as regions round St. Petersburg, Yaroslavl, Gorki, Kazan and Ufa. All these regios were characterised by instable seed yields of leguminous fodder crops. The vegetation period in those regions lasts for 80...100 days.

The central and southern parts of the zone have favourable conditions for galega growing. This area covers the Baltic States and Byelorussia, the territories surrounding Pskov, Novgorod, Moscow, Pensa, Vladimir, Kostroma, Kirov, Rjazan and Gorki and also Mordovia, Tatar, Bashkiria, Mari and Chuvash.

All in all, the Estonian Research Institute of Agriculture has sent galega seeds to 33 territories and 6 republics of the former Soviet Union. As feedback, valuable information on the winterhardiness and drought resistance of galega, as well as on the seed and green material yields has been obtained.

Positive results of fodder galega growing have also been obtained from Canada. A lot of studies were conducted across Canada to compare the herbage productivity of fodder galega to that of traditional forage legumes, in order to assess its agricultural potential (Fairey et al., 2000). The average annual dry matter yield of fodder galega was 5,5 t ha^{-1} during the first three production years. The performance characteristics of galega indicated that it could have considerable agricultural potential as an additional, perennial, herbage legume for many regions of Canada.

The Estonian Research Institute of Agriculture has had long-term contacts with Finland in the field of galega research. At the Department of Plant Husbandry of the University of Helsinki, field trials were started in 1978 (Varis, 1986). At the same time the Departments of Microbiology (Lindström, 1989) and Animal and Plant Husbandry commenced microbiological and feeding studies and the department of Pharmacology some alkaloid studies (Laakso et al., 1990).

In Denmark the Plant Breeder of Pajbjergfonden and the Royal Veterinary and Agricultural University and several other research establishments participated in the research work with fodder galega.

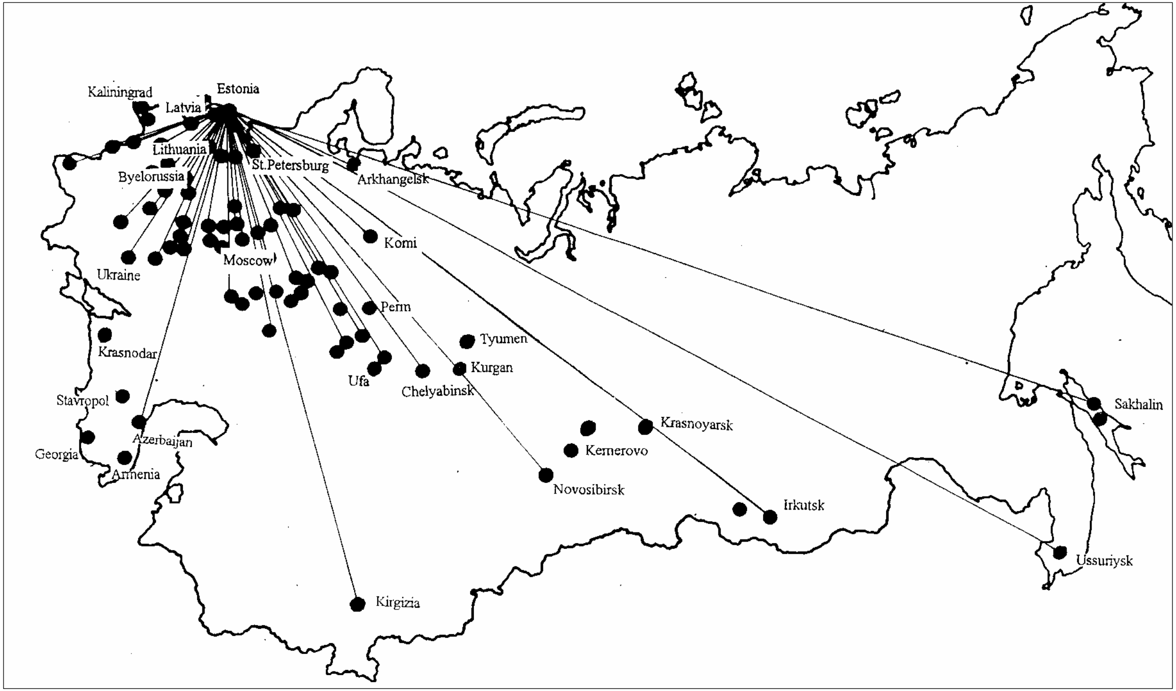

Figure 3. *The main territories and capitals of the former Soviet Union where galega seeds were sent from Estonia in 1980s-1990s*

In 1980s-1990s a lot of experiments with galega were started in different countries (Norway, Sweden, Poland, Yugoslavia, France, Italy, Greenland). In general there was a high interest among farmers to establish smaller fields with this new forage crop. A more intensive introduction and widespread use, especially on poorer sandy soils were being expected. But further field experiments are needed in order to find out the optimal management for galega growing under different soil conditions.

In addition to the above-mentioned countries, experiments with the fodder galega have been carried out also in Germany, Chile, Great Britain, Hungary and USA.

One of the recent collaboration agreements was concluded between Hokuren Livestock Experimental and Training Farm in Hokkaido in Japan and the Estonian Research Institute of Agriculture. The purpose of this agreement is to research, evaluate and pursue studies on the new fodder plant *G. orientalis* and to determine its adaptability under the conditions of Hokkaido as well as the acceptability and consumption of galega's herbage by dairy cattle.

2. BIOLOGICAL CHARACTERISATION OF FODDER GALEGA

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2.1. Botanical characteristics of fodder galega

Fodder galega (*Galega orientalis Lam.*) belongs to the family of legumes (*Leguminosae*) and genus of goat`s rue (*Galega*) (Figure 1).

The genus of goat`s rue consists of 7 plant species and they are spread over Caucasus, Central Asia, the Mediterranian countries, the Balkan countries, Iran, South America and Central Europe. The most well-known and with the broadest spread is *Galega officinalis* L., which grows in nature in all the above-mentioned areas. *Galega orientalis* Lam. originates from the regions of the Caucasian subalpine belt, where it has been found growing as an endemic plant species (Grossgeim, 1930). Its natural growth areas are Armenia, Georgia, Dagestan and Azerbaidzhan (Flora USSR, 1945).

Figure 1. *Fodder galega (Galega orientalis)*

Fodder galega is a perennial tap-rooted herb, which spreads and propagates also vegetatively by underground stolons or rhizomes. The root system of galega consists of several roots: tap-, lateral and additional roots. In the first year the roots are light brown, year by year they get darker together with plant`s ageing. The root system is vigorous but located mostly near surface, penetrating into soil only until 60…70cm. The main root is well developed, with a lot of lateral roots and can reach into the depth of more than a metre. In the depth of 3…7 cm side branches or rhizomes of a stem with 3…4 buds are formed on the main stem. Rhizomes spread in soil horizontally up to 15…30 cm, thereafter they head for ground and form new above-ground shoots (Figure 2). These underground stems are also the place for keeping the gathered food reserves during vegetation period, on which the vegetative propagation and reforming of herbage depends. A lot of buds can also be found on a root crown, from which the development of underground stolons and reforming of herbage is continued. Thus galega propagates and spreads both generatively and vegetatively due to which plant stand will not thin with years but on the contrary, will get thicker.

Figure 2. *New shoots of fodder galega develop also from buds on underground stolons*

Round root nodules are located on galega roots, containing nitrogen fixing bacteria *Rhizobium galegae* (Figure 3). These microsymbionts-bacteria of galega are host-specific and do not belong to any other earlier discovered fast growing species of bacteria situated in root nodules (Lindström, Gyllenberg, 1988).

Figure 3. *The root system of fodder galega with round root nodules and underground stolons*

The height of fodder galega plants varies between 60 and 150 cm. Branch stems are in the middle and upper part of the main stem. The leaves are compound and consist of 5 or 6 pairs of egg-shaped leaflets. There are a few flower clusters on the stem, containing 25 to 60 bright lilac flowers.

Galega fruit is a pod. The pods are 2 to 4 cm long and contain 5 to 8 kidney-shaped seeds. The weight of a thousand seeds is 7.0 to 8.0 g. The seeds are yellowish green in colour, later light brown.

The two most well-known species of the genus of goat`s rue (*Galega*) *Galega orientalis* Lam. and *Galega Officinalis* L. differ from each other botanically. In Table 1 the botanical comparison of the two species is given.

Table 1. *Botanical comparison of Galega orientalis Lam. and Galega officinalis L.*

Characteristic	*Galega orientalis* Lam.	*Galega officinalis* L.
Root	tap-root with rhizomes	tap-root no rhizomes
Stem	erect height 60…150 cm	erect height 50…120 cm
Leaf	compound leaf 5…6 pairs of egg-shaped leaflets	compound leaf 5…8 pairs of lineal leaflets
Stipules	round-leaved	lancet-shaped
Flower	raceme bright lilac	raceme light lilac
Fruits	pods hang	pods erect

Fodder galega does not suffer from any serious fungal, viral or bacterial diseases, or insect or nematode pests at the present time.

For now, according to the data gathered by P. Soobik (Estonian Institute of Agriculture) there are three pathogenic species of fungi specialised strictly on galega: *Pernospora galegae* Sav. et Rayss. (its findings have numerously been collected from the mentioned species at the end of summer), *Ramularia galegae* Sacc. (with considerably conservative frequency) and *Cercospora galegae* Sacc. (there is only one finding for proving the occurrence).

Patogenic fungi of galega are mostly formed by microfungi living on many legumes or several other representatives of cultivated plants. But in local conditions they are of no importance as injurious species since no considerable pathogen occurrences have been found which could disturb galega plants significantly.

2.2. Growth and development characteristics of fodder galega

When solving the adapatation problem of a new fodder crop galega, regional peculiarities of our soil and climatic conditions had to be considered.

The climate of Estonia is moulded by intensive cyclonic activities both in the northern part of Atlantic Ocean and proximate nearness of the Baltic Sea and its bays. Due to that the weather is very changeable. Vegetation period with the temperature over 5°C lasts for 170-180 days and during this time precipitation in the continent of Estonia is 275-330 mm, on the islands and west coast 220-275 mm. The sums of precipitation differ by years and their distribution in spring and summer is irregular. There are often periods with little rainfall (drought) or with too much rain which worsen the growing conditions of field crops a great deal or in a slight degree, complicate sowing and harvesting work and cause big amplitudes in yield.

Although winter is of maritime nature, the absolute minimum of air temperature has been observed from -31°C to -35°C on the islands and coast and down to -43°C inland. The freezing depth of soil depends on the thickness of snow. The snow cover is thicker in February and March, 30-35 cm on the average. Often enough several winter damages of cereals and perennial grasses occur. E.g. lucerne sowings of southern origin are not often winterhardy. Cultural crops are also jeopardised by spring night frosts in vegetation period, especially during blooming. The first early night frost in autumn also ends the growth of plants and damages the yield.

Diversity of Estonian soils is due to the bedrock and relief. Mostly sod-calcareous, sod-podzolic, half-bog soddy and bog soils have spread in Estonia. Sod-calcareous soils of North Central and West

Estonia have been formed on Silurian limestone and on calcerous moraine. South-Estonian sod-podzolic soils have been formed on Devonian loamy red-brown moraine, they are mostly with acid reaction and in several places with hilly relief and also sensitive to erosion.

Since this species originates from mountainous regions of Caucasus and grows in that region starting with 300…400 m up to 2000 m above sea level, it can be assumed that it also grows in colder climate conditions. After the first adaptation experiments it became evident that the plant adapted very well in our conditions and turned out to be more winterhardy than other varieties of fodder galega from southern areas. Galega has been tolerant to winter temperatures of -30°C down to -40°C under snow cover and down to -20°C on uncovered field. During spring growth plant leaves tolerate night frosts of -5°C down to -7°C and at the beginning of flowering down to -4°C.

Winterhardiness of galega depends a lot on its cutting regime. Overwintering is very good when using a two-cut system whereas the second cut is made later in autumn, e.g. at the end of September or beginning of October. There can be no cut at the end of August or beginning of September as in that case by the end of vegetation period the plant will use reserves gathered in underground stolons for regrowth and will not survive well during hibernation.

Galega is well adapted to our soil conditions. It does not grow on acid soils (pH<5.7) since nodule bacteria situated on roots do not tolerate acid reaction of the soil and die. Galega grows well on drought-sensitive sod-calcerous soil on limestone in North and West Estonia and on the islands where it has often shown to be more drought resistant than other leguminous fodder crops (inc. lucernes). Galega grows also well on hilly landscape of South Estonia, where are very variable soils. Its yield is high enough and quite stable compared to other field crops. It also helps to avoid erosion there.

In our conditions, galega starts its growth in spring at the end of April, depending on weather conditions (the average of many years has been about April 27). After 8 up to 14 days the stems will start to grow fast. At the end of May flower buds will start to form, beginning of flowering is about 12-19 of June, the period of full flowering is at the end of June. Depending on weather conditions the seeds ripen usually by the first half of August, sometimes in the beginning of

September. It takes about 114 days from the beginning of growth in spring until harvesting. The average correlation between the development stage of the plant, days and dates needed for passing these stages in our conditions are shown in Table 2.

Table 2. *The average correlation between development stage and days and dates needed for passing the stage (Nõmmsalu, 1993)*

Development stage	Growing days	Dates of passing the stage
Starting the growth in spring	1-9	27.04-05.05
Shooting	10-30	06.05-26.05
Budding	31-46	27.05-11.06
Beginning of flowering	47-54	12.06-19.06
Full flowering	55-65	20.06-30.06
End of flowering	66-74	01.07-09.07
Seed maturing	75-113	10.07-17.08
Seed gathering	114	18.08

Galega herbage renews after cutting mostly by new stolons formed from buds located mostly on a root crown and rhizomes, and the growth of the second cut is fast and good. The yield from the 2nd cut can be approximately one third of the yield gathered during the first cut. The growth of plants is often irregular – e.g. by the beginning of October a part of the plants have formed flower buds already and started blooming, a part of them are in the stage of shooting yet.

Galega is characterised by high percentage of leaves. The role of foliage in green mass is the biggest in the stage of shooting (45-57% on an average), by the beginning of flowering it decreases down to 40-35%. The 2nd cut is with a thicker foliage where the percentage of leaves in green mass is 45-65%, reaching sometimes up to 70%.

The arhitectonics of herbage of galega field and radiation regime have been studied in Estonia in the years 1975-1978 (Tammets, Tooming, 1983). In trial fields the height of the plants was 120-150 cm and density 216-308 stems per m^2. The total assimilation area (leaves+stems) was 14-15 m^2. The assimilation area is the biggest and the phosynthesis and formation of green biomass most intensive in the upper layer at the height of 80-100 cm. By the indicator of assimilation area galega overcame the density of maize grown for green mass.

From the investigations on phytosynthetically active radiation it became out that galega leaves had good light transmission. So the active radiation reaches also the lower, overshadowed leaf layers. Radiation is divided in the herbage between different layers quite evenly and finally is absorbed almost entirely. By that the great production ability of galega can probably be explained.

3. AGROTECHNOLOGY

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3.1. Soil cultivation

Fodder galega can be grown almost on every soil type. Loamy automorphic (non-gleyed) soils are more suitable for galega fields. Good yields are also received on drained gley and alluvial soils. Fodder galega does not tolerate staying surface water, high ground-water level and acid (pH_{KCl} below 5.7) soils. The soil reaction should be close to neutral, like in case of most legumes. Fodder galega grows badly on acid and poor in nutrients soils, the plant cover in this case is weak and is usually become damaged during the first winter.

Fodder galega should be sown early in spring. Therefore the soil cultivation should be done on time and of high quality in autumn. Special attention should be be paid to weed control (stubble disking), especially exploitation and eradication of perennial weeds (common coach grass, field sow thistle, dandelion, etc.). Cleaning the surface layer of soil by eradication of weed sprouts, surface-levelling of the field and preparation the dense seedbed – these are the main objectives of presowing cultivation.

The seedbed must be prepared carefully. The soil must be firmed and free of weeds. A compromise should be made so that the seedbed was neither too fine nor too cloddy. A firm seedbed helps to keep the soil from drying out rapidly and prevents the seed from being planted too deep.

It is essential that the seeds of galega should be sown no more than 1,0...2,0 cm deep into heavy soils and up to 2,5 cm into the lighter ones.

3.2. Fertilisation

Galega needs first of all potassium and phosphorous fertilisers (Table 1).

In the trials established on gley soil with average P and K content and with fertilising doses of $P_{90}K_{120}$, up to 60 t ha^{-1} of fresh material were received from one hectare, in case of unfertilised variant only 24 t ha^{-1}, i.e. more than two times less. Thus growing galega without sufficient amount of P-K fertilisers does not give the desired results. P-K fertiliser has to be given according to their content in soil and the method of establishing galega field. In the sowing year PK-fertilisers are expected to be given also as a reserve fertiliser.

Fertilisation with 30 kg of nitrogen per hectare in the case of pure stand and with 60 kg of nitrogen in the case of a cover crop given at sowing, favours the initial development and growth of galega plants on soils with low fertility and humus content.

In mixtures of galega and grasses 40…60 kg of N given in the second year of utilisation increases the productivity of mixtures. The bigger doses of N-fertiliser decrease the share of galega in plant cover and total protein production.

Acid soils have to be limed before sowing. Better results have been received when giving lime in parts – 2/3 before sowing and 1/3 very close to the sowing before harrowing or rolling (1...2 t ha^{-1}).

The organic fertiliser (40...60 t ha^{-1}) should be given to a preceding crop.

Table 1. *Galega`s need for fertilisation*

Content of nutrients in 100 g soil (mg)	Application	In the year of sowing		In the 2nd and following years of growth
		Without cover crop	Sown under spring cereals	
Phosphorous			P_2O_5-fertilisation (kg ha^{-1})	
4.6 - 11	average	200	275	100
11.1 - 24	small	160	220	80
> 24	very small	70	160	60
Potassium			K_2O-fertilisation (kg ha^{-1})	
5.1- 10	high	360	405	180
10.1 - 20	average	320	325	160
> 20	small	280	295	140
In the year of establishment 30 N				

3.3. Seed preparation

Galega is a leguminous plant which has nodule bacteria on the roots. Plant`s normal development, growth and winterhardiness depend on the existence of nodule bacteria in the soil. When growing galega for the first time, seeds have to be inoculated with a corresponding nodule bacteria. Nodule bacteria are specific, i.e. the ones which are suitable for lucerne and clover, not suitable for soya, melilot and not at all suitable for galega.

Inoculated seeds of galega should be preserved in a cool place, it is even better to sow them out into humid soil (e.g. after raining). If sowing background is favourable, nodule bacteria will multiply in the soil real fast, penetrate into roots through roots` hair and form nodules there. As the source of energy they use carbohydrates from the plant, giving in return fixed compounds of nitrogen. So a useful symbiosis will develop between a plant and bacteria.

The development of nodule bacteria on the roots of galega can be observed already in the second half of summer. The effectiveness of symbiosis between a plant and bacteria will greatly depend on moisture and acidity of soil. There are a few nodules on the roots of galega plants in fields with late sowing time and fields suffered from drought. Plants are weak and light green and die during over-wintering. Dark green vigorous plants certainly prove that nitrogen is fixed intensively (Figure 1).

Figure 1.*The influence of inoculation on the development and growth of galega plants: 1 - not inoculated; 2, 3 - inoculated*

In a trial established on sod-calcerous soil on limestone the influence of seeds` inoculation on galega's productivity was studied, depending on the number of bacteria in a bacterial preparation (Table 2). The trial results show that growth and development of galega depends directly on inoculation of seeds and quality of bacterial preparation. The influence of the preparation with a small number of bacteria was close to the control variant.

Table 2. *The effect of inoculation on galega's dry matter yield and its quality on the sowing year*

No of bacteria per one seed	Dry matter yield	Crude protein content
	t ha^{-1}	%
200 000	6.13	14.9
40 000	5.77	15.4
2 000	1.91	10,5
control	0.84	10.8

Bacterial preparations and pesticides must not be used together.

Scarification is also an important method in preparing seeds for sowing. Quite a high percentage of seeds (50...68%) is covered with a hard seed cover. Scarification favours the germination of seeds in the sowing year.

Scarification can take place 5...7 days before sowing and it should be done with a special for this purpose made machine.

3.4. Sowing rate and row space

Sowing rate and row space are depend on the purpose of galega growing, quality of seeds, sowing method and other conditions.

Galega fields are usually established with the narrow row space of ca 10…30 cm for getting fresh material for green fodder or making silage and with the wide row space of ca 45…60 cm for getting seeds.

The production of fresh material and seeds depends directly on density of plant cover. Sowings with low density and with a good lighting regime give high seed yield but maximum herbage are received from sowings with higher density.

It is also practical to establish galega field sometimes with a wide row space (45…60 cm) for producing green fodder. Tillering between the rows is carried out in the sowing year in every case, which favours the growth and development of underground stolons and controls weeds. As galega spreads and multiplies also vegetatively this plant is capable to regulate the density of plant cover by itself by vegetative propagation. Because of the vegetative propagation the multiplication coefficient of galega is extra high.

Sowing rate depends on the purpose of use the field: for green fodder with the narrow row space – 20…30 kg ha^{-1}, for establishing seed fields with the wide row space – 6…8 kg ha^{-1}.

In order to find out how row space influences the herbage production, pure sowings with the row space of 12.5 cm, 25.0 cm and 50 cm with sowing rates accordingly 40, 20, 10 and 15 kg ha^{-1} were established. For investigation the vegetative propagation and spread of galega, the tillering between the rows was not used. It became evident that the growth density and herbage yield practically equalised on the 4th year of use, irrespective of sowing method. Nevertheless in sowings with wide row space (50 cm) 21…27% of dry matter was not received.

Table 3. *The influence of sowing depth on emergence of galega seeds on clays (Raig1980)*

Size of seeds	Mass of a 1000 seeds, g	Percentage of seeds` emergence Sowing depth, cm			
		1	2	3	5
Big	7.39	63.7	56.9	25.2	
Small	7.04	31.2	22.2	-	-
Not sized	7.30	45.2	46.2	16.5	14.2

The germination of galega seeds depends on the size of the seed. Bigger, well developed seeds germinate better than the small ones. The optimum sowing depth is 1…2 cm depending on soil texture and humidity (Table 3). Pre- and after-sowing rolling creates favourable germination conditions for seeds.

It is also possible to sow galega under cover crop. In sowings under cover crop (for example early summer barley) it is possible to improve lighting regime by decreasing the sowing rate of a cover crop by 25…50% and regulating the row space. Good results have been achieved by every other row sowing, with the row space of 20…35 cm. It is important to decrease the sheltering effect of cover crops.

3.5. Sowing time

Galega's growth and development depends on sowing time. Although the seed`s optimum germination temperature is 10…12°C, it does not mean that sowing could be delayed in spring and wait for optimum temperature.

In trials the best results were received from the variants with sowing time in May. Galega plants which were sown in June, but especially in July and August, started to develop and grow slowly, plant cover remained thin and got infested with weeds, plants were weak and pale green.

Overwintering of galega plants depended also on sowing time. Of stands sowed in May, overwintered 95…100%, of stands sowed at the end of July – 52% and in August, only 12.8%. Late sowing time did not favored the vigorous growth of galega plants on the next year, i.e. from stands sowed in August it was received 0,5…2,4 t ha^{-1} of dry matter only. Although in the third year of growing the yields started to conform between the different sowing times due to vegetative propagation and spread of galega, the yield losses were due to late sowing time, as an average of 4 years, very big, reaching in stands sowed in July up to 11.5…32.9% and in stands sowed in August up to 23…28.3%. Dry matter yields of galega and the changes in the production depending on the year of growth are shown in Table 4.

On the basis of a long-term experience it can be confirmed that galega needs early sowing, e.i. sowing on the first opportunity. All presowing activities – field selection, soil cultivation, weed control and fertilisation have to be carried out already in autumn; so the necessary preconditions for early sowing will be established.

Table 4. *The effect of sowing time on dry matter yield of galega (t ha^{-1}) (Raig, 1980)*

Sowing time	Year of growth					5-year average	%
	1.	2.	3.	4.	5.		
17.05	5,8	9,3	11,3	7,1	8,6	8,4	100
17.06	5,7	7,9	10,9	6,6	9,1	8,0	95
17.07	1,3	6,1	9,2	6,1	8,1	6,2	73
10.08	4,8	6,9	9,9	7,0	8,4	6,5	78

3.6. Sowing under cover crop

Galega plants in pure stands have more favourable growth and development conditions, but a lot of annual weeds could be found there. Sowing under cover crop enables the better control of weeds on galega field on the first year of growth.

In order to study the effect of cover crop and fertilisation on the growth of galega plants the field trials were established with different fertiliser applications. The cover crop spring barley Otra was sown on May 17 with the row space of 10.5 cm, galega was also sown on the same day. Barley shoots were cut for fodder on June 26 in some variants. Also the weeds grown in the upper layer were cut in the variant without a cover crop. By that time galega in a pure stand had developed into 4…5 true leaves. Barley in full maturity was harvested on August 13 and the growth and development of galega were the worst in this variant (Table 5). Plants grown under barley were weak and bright green.

The yield of barley depended on fertilisers. 3,2 t ha^{-1} was received at fertilisation with 120 kg of P_2O_5 and 120 kg of K_2O and no nitrogen per hectare, 5,2 t ha^{-1} with the same fertilisation rate + 40 kg of nitrogen and 5,6 t ha^{-1} with the same fertilisation rate + manure. The trial results indicated great positive effect of mineral fertilisers and manure on barley yield (extra yield being 2,1…2,4 t ha^{-1}), which in turn had bad influence on under sowed galega. Winterhardiness of galega diminished in this case.

The effect of a cover crop and fertilisation on galega's dry matter yield in the above mentioned trials is shown in Figure 2. From that we can see that the dry matter production of galega stand from the first year was so much higher the less competition could be found for the growth place in the plant cover. The higher dry matter yields were received from pure stands of galega. The differences between variants decreased at the following years. The highest total dry matter yield of 6,6-7,2 t ha^{-1} was received due to the use of PK-fertilisers and no N application.

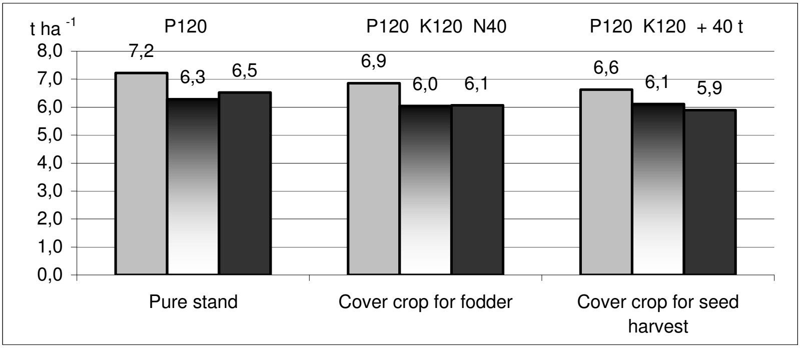

Figure 2. *The effect of a cover crop and fertilisation on dry matter yield of galega (on the average of 1975…1978)*

Table 5. *The effect of a cover crop and fertilization on galega's dry matter yield (t ha $^{-1}$) (Raig, 1980)*

Sward	Cut	$P_2O_5$120 K_2O120						$P_2O_5$120 K_2O120 N40						$P_2O_5$120 K_2O120 + 40t manure					
		1975	1976	1977	1978	sum	mean	1975	1976	1977	1978	sum	mean	1975	1976	1977	1978	sum	mean
Pure stand	1.	4,5	3,8	6,5	3,7	18,5		2,9	3,4	6,5	3,7	16,4		4,2	3,4	6,1	3,9	17,7	
	2.	-	3,7	2,4	4,3	10,4		-	2,2	2,0	4,6	8,7		-	2,3	2,3	3,8	8,4	
	Total	4,5	7,4	8,9	8,0	28,9	7,2	2,9	5,6	8,4	8,3	25,1	6,3	4,2	5,7	8,5	7,7	26,1	6,5
Cover crop	1.	3,9	4,1	6,2	3,6	17,8		2,5	2,1	6,7	3,8	15,1		3,4	2,6	6,6	3,8	16,4	
for fodder	2.	-	2,5	2,6	4,6	9,6		-	2,2	2,6	4,3	9,1		-	1,8	2,4	3,8	7,9	
	Total	3,9	6,6	8,7	8,2	27,4	6,9	2,5	4,3	9,2	8,1	24,2	6,0	3,4	4,4	9,0	7,5	24,3	6,1
Cover crop for seed harvest	1.	4,1	3,2	6,0	3,3	16,6		1,6	3,0	6,5	4,3	15,4		2,3	2,9	6,4	4,3	16,0	
	2.	-	3,5	1,9	4,5	9,9		-	1,5	2,3	5,2	9,0		-	2,3	3,5	3,5	9,4	
	Total	4,1	6,7	7,9	7,9	26,5	6,6	1,6	4,5	8,9	9,5	24,4	6,1	2,3	5,3	9,9	7,8	25,3	5,9

3.7. Treatments on galega field

The initial development and growth of galega plants is slow. Therefore it is of relevant importance to apply several treatment methods here.

Seeds need moisture for germination. The field has to be rolled just after sowing for improving the contact between seeds and soil. The weight of the roller is chosen according to moisture content of soil. By rolling, the soil is surface-levelled.

Due to slow development speed of galega plants pure stands of galega suffer from infestation with weeds at the first year of growing. The productivity of galega in stands sowed under cover crop decreases considerably in the first and second years of growing, but suppression of weeds is more effective there. Chemical weed control has to be carried out both in pure stands and stands with a cover crop.

For controlling annual weeds like *Sinapis arvensis* L., *Viola arvensis* Murr., *Thlaspi arvense* L., *Polygonum* spp., *Tripleurospermum inodorum* L. the herbicides MCPA-1.0 l ha^{-1}, Basagran (contains 480 g l^{-1} of bentazone as active ingredient) 3.0-4.0 l ha^{-1} or MCPB 2.5-3.8 l ha^{-1} are being used. Tank mixtures with Stomp (330 g l^{-1} of pendimethalin) are also well suitable: Stomp 1.5-2.0 l ha^{-1} + MCPA 0.5 l ha^{-1} or MCPB 1.5-2.0 l ha^{-1} or Basagran 1.0-2.0 l ha^{-1}. Basagran 1-2 l ha^{-1} in the mixture with MCPA 0.5 l ha^{-1} or MCPB 1.5-2.0 l ha^{-1} will also do. Mixtures of different herbicides are better since the effect on different weeds usually increases. The impact range of MCPA is similar to MCPB, Stomp improves the effect on hemp nettles, field pansy and fumitory, Basagran on corn mayweed and goose grass. Galega must be in the stage of 2-3 true leaves at the time of treatment.

Starting from the second or third year of use, galega will, unlike the other perennial legumes (lucerne, clover, etc.), phase out from its thick upper layer of plant cover into lower layer such perennial weeds like *Tussilago farfara* L., *Cirsium arvense* (L.) Scop. but not *Elytrigia repens* (L.) Desv. For coach grass herbicides Agil (100 g l^{-1} of propaquizafop) 1.0 l ha^{-1}, Zellek Super (108 g l^{-1} of haloxyfop-R methyl ester) 2.0 l ha^{-1} and Fusilade Super (125 g l^{-1} of fluazifop-p-butyl) are used.

Since the third year of use, the galega field with normal density is almost free of weeds. It is due to vigorous growth of galega and shading of lower layers. In older galega fields (more than 8 years) the spread of perennial weeds like *Aethusa cynapium* L., *Cirsium arvense* (L.) Scop, *Artemisia vulgaris* L., *Urtica dioica* L. has been observed. For controlling the weed centres the herbicide Roundup (360 g l^{-1} of glyphosate) with overall control effect or its analogues – Glialka (360 g l^{-1} of glyphosate), Glyfos (360 g l^{-1} of glyphosate) etc. should be used locally.

3.8. Irrigation

The series of irrigation trials were established on drought-sensitive sod-calcerous soil on limestone in 1975, 1976 and 1980. Ground water from a drilled well (9…10°C) and water warmed up in a reservoir (13.5°C, 17°C and 21°C) was used. The fertilisation rate was 120 kg of P_2O_5 and 120 kg of K_2O per hectare. The weather of trial years was drier than the long-term average. The difference from the precipitation rate was 30 mm in 1975, 147 mm in 1976 and 23 mm in 1980, therefore irrigation was effective at these years (Table 6).

Each mm of irrigation water gave an extra dry matter yield of 17...22 kg. When using cold water from drilled well and warmed reservoir water, the warmer water gave the 10...23% increase in the productivity.

Table 6. *The effect of irrigation on galega's productivity on sod-calcerous soil on limestone (Raig, 1980)*

Year	Irrigation rate	Temp. of water for irrigation	Dry matter yield	Extra yield due to irrigation		Yield of nonirrigated variant
	mm		t ha^{-1}	t ha^{-1}	%	t ha^{-1}
1975	96	10	11,2	2,1	23	9,1
	93	17	12.1	3,0	33	
1976	97	9	8.6	1.6	23	7,0
	97	13.5	10,2	3,2	46	
1980	24	10	8,4	0,4	5	8,0
	24	21	10,0	2,0	25	

For example at Adavere large-scale farm irrigated grasslands have been established on slightly podzolized and leached loamy sands and loams. Irrigated area (317 ha) give usually 2...4 cuts. Seed mixtures for establishing irrigated grasslands included also galega. Mostly mixtures with galega, cocksfoot and red clover are dominating. Grass swards rich in bastard lucerne and smooth bromegrass are also used. Irrigation rates which have been used are very different yearly: from 30 mm up to 193 mm. The 11-year average irrigation rate is 78 mm and the number of irrigations 2.5.

Use of irrigation can be one possibility in galega fields to increase the production. The extra yields due to irrigation and stability of production can confirm it.

3.9. Some peculiarities of mixtures' agrotechnology

The choice of components for mixture, their share in the sward and sowing rate depend on soil characteristics, its water regime and also on the utilisation of sward.

Galega does not usually survive in the fields which locally suffer from surface water or have variable texture and acid reaction. Grasses are more resistant in these conditions and growing them together with galega will increase the production stability of sward.

Smooth bromegrass (*Bromus inermis* L.), meadow foxtail (*Alopecurus pratensis* L.) and reed canary grass (*Typhoides arundinacea* L.) are the grasses which development and growth are suitable for growing together with galega on moist areas. Of drought-resistant grasses timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Huds.) and cocksfoot (*Dactylis glomerata* L.) should be included in mixtures.

The share of galega in the mixture is usually 40...60%, the sowing rate is 15...20 kg ha^{-1} and row space is 20...25 cm. Grasses can be sown vertically with galega rows.

Mixtures are also less infested with weeds in the year of sowing.

4. SEED GROWING

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Seed growing of fodder galega is much more simple in Estonian weather conditions and getting seed is more stable when in case of lucerne and clover. Although it is possible to obtain seed from swards intended for growing fresh material, the lighting conditions, etc. are better in specially established seed fields with a wide row space and the obtained seed yield in this case is significantly higher.

In 1976 fields for harvesting seed yield with a row space of 60 cm, sowing rate of 10 kg ha^{-1} on three types of soil were established: Variant 1 – sod-calcerous soil on limestone, variant 2 – sod-podzolic soil, variant 3 – leached sod-calcareous soil. As an average of 10 years, 230...420 kg of seeds were received per one hectare. PK fertilizer (90 kg of P_2O_5 and 60 kg of K_2O) was given every year since establishing the seed field. The yield results are given in Table 1.

Table 1. *Seed yields (kg ha-1) of galega in long-term large-scale trials, 1977…1986 (Raig, 1988)*

Year	Var.1 Sod-calcerous soil on limestone	Var.2 Sod-podzolic soil	Var.3 Leached sod-calcareous soil
1977	236	201	780
1978	427	182	339
1979	240	265	700
1980	207	198	652
1981	204	210	266
1982	450	420	400
1983	430	363	330
1984	130	275	0
1985	415	100	353
1986	316	200	416
average of 10 years	305	241	424

The seed yield depends essentially on soil, temperature during the flowering time and precipitation. Higher yields were received on soils with high lime content (var. 1&3). In 1984, in the beginning of June, at the time of flowering the night frost (from -1 down to -2°C) damaged flowers and decreased the seed yield considerably (var. 1) and caused total failure of seed yield (var.3).

Comparing the seed yield of galega to the seed yield of hybrid lucerne, which Estonian statistical average seed yield is 70 kg ha^{-1}, the seed yields of galega are 3...6 times higher.

It also became evident that by using the above-mentioned sowing rate (10 kg ha^{-1}) the plant cover of these fields was too dense as a result of which the light regime became worse, plants lodged and the yield decreased in total. In order to find out the optimum sowing rate, supplementary trials with the sowing rates of 4-6-8-10 kg ha^{-1} and with the row space of 62.5 cm were established. In the second trial there were different row spaces - 12.5; 25.0; 37.5; 62.5 cm. The sowing rate was 40 kg ha^{-1} and sowing depth was 2.0 cm.

The vegetation period of 1989 started early, the average air temperatures of May and June were +1...+1.7°C degrees higher than the usual ones, the amount of precipitation in June was 75 mm, i.e. 129% of the norm. The highest seed yield – 690 kg ha^{-1} – was obtained in 1989 with a wide row space (62.5 cm) and the sowing rate of 4 kg ha^{-1} (Table 2). Analogical results (654 kg ha^{-1}) were received with the wide row space and a relatively high sowing rate (40 kg ha^{-1}) (Table 3). In the following year, i.e. in 1990, galega's seed yield decreased. In spring the growth and development of plants were slow due to frequent night frosts. The amount of precipitation in May and June was lower, i.e. 51% of the norm. As galega has a strong root system, the summer drought did not considerably affect the seed yields of the variants. The trial results indicated that in the 3rd year (1991) the seed yield did not depend on the sowing rate, but still depended on the row space. The plant cover density of the swards sowed with wide row space (62.5 cm) was still thinner and yields amounted to 270.9 and 378.1 kg ha^{-1}.

The trial results of 1993 were very much affected by the night frosts in June (-1...-3°C). Galega was then at the stage of flowering; therefore the seed yields remained lower – 120...149 kg ha^{-1}.

Table 2. *The dependence of galega's seed yield on sowing rate (Meripõld, 1994)*

Var	Row space	Sowing rate	Seed yield, kg ha^{-1} 1989	1990	1991	1992	1993	5-year ave-rage
1	62.5	10	619.0	270.9	289.8	214.0	149.6	308.5
2	62.5	8	647.0	378.0	327.6	228.0	148.2	345.7
3	62.5	6	612.0	365.4	378.1	269.0	120.6	349.0
4	62.5	4	690.0	428.9	302.4	221.0	144.1	357.0

Table 3. *The dependence of galega's seed yield on row space (Meripõld, 1994)*

Var	Row space	Sowing rate	Seed yield, kg ha^{-1} 1989	1990	1991	1992	1993	5-year ave-rage
1	12.5	40	401	283.5	220.5	234.0	128.9	253.6
2	25.0	40	563	303.0	239.4	152.0	120.0	275.5
3	37.5	40	570	306.9	264.6	231.0	131.7	300.8
4	62.5	40	654	294.1	270.9	193.0	120.0	306.4

In conclusion, according to the field trial results, the average seed yield of 5 years was 253...357 kg ha^{-1}. The highest seed yields (612...690 kg ha^{-1}) were obtained in the 2nd production year with a wide row space (62.5cm). The optimum sowing rate was 4...6 kg ha^{-1}.

Sowing rates over 6 kg ha^{-1} did not increase seed yields. The fact that seed yields have become more homogenous over years is caused by intensive vegetative propagation of galega as well as by self-regulation of plant stems density.

For now the great advantages of fodder galega compared with other leguminous crops concerning the obtaining of seed yields have become obvious. It is very important that fodder galega is able to give a stable seed yields in regions where it is not possible to obtain a good seed yield from lucerne (Raig, 1993; Nõmmsalu, Meripõld, 1996).

Seed yield of fodder galega depends significantly on establishment and field work. Lime-rich mineral soils with normal moisture regime are suitable for seed growing. Sowings without a cover crop with a wide row space (45...60 cm) should be preferred, which will give seed already at the next year. Sufficient sowing rate is 4...6 kg of seed per hectare.

The seed`s pre-sowing inoculation with a special bacterial fertiliser is essential.

The soil should be well cultivated and levelled and made dense by a land roller pre- and after sowing in order to get the even sowing depth (1-2 cm). P-K fertiliser should be given according to soil characteristics in the proportion 1:1 both before establishing the seed field and early spring or autumn of the each growing year.

With the object of weed control, the field should be treated with herbicides in the sowing year. Also tillering can be used between the rows or weeds can be controlled by cutting. Using the tillering between the rows for thinning the plant cover, it has to be continued also at the following years, usually in spring.

The seed yield must be cleaned from the seeds of foreign species and weeds, which seeds are distinguished from the others.

Galega starts blooming at the end of May or in the beginning of June, depending on spring, and it lasts for 1...2 weeks. Due to large open blossoms, bees and bumblebees like to visit galega plants and it helps in increasing the seed yield.

5. BREEDING OF FODDER GALEGA

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5.1. The potential for breeding an improved fodder galega

Fodder galega is a "young" crop (domesticated only about 70 years ago) which does not have a prolonged cultivation and breeding history (Rollov, 1908; Simonov, 1938; Raig, 1988; Nõmmsalu, 1993).

The first galega variety Gale was produced in Estonia by the specialists of the Research Institute of Agriculture (H. Raig, J. Metlitskaja) and All-Russian Institute of Fodder Crops (S. Simonov, Z. Jartieva) by using mass selection. In Estonia the variety Gale has been on the official variety list since 1988.

In 1985...1990 official trials of variety Gale were carried out in 65 cultivar control stations which situated in areas with different climatic conditions on the territory of the previous Soviet Union. The obtained research results indicated that galega variety Gale was in the north-western and northern region of Europe not inferior, and by some parameters even superior to the basic fodder crop lucerne. The superiority of Gale in seed production was especially evident in northern growing areas (Metlitskaja, 1992).

The variety Gale is used not only as a forage plant but also as a crop for soil improvement (Raig, 1994).

The galega possesses a high intensity of symbiotrophic nitrogen nutrition due to the symbiosis with root nodule bacteria (*Rhizobium galegae*). In Estonia the *Rhizobia* inoculation can improve galega yield by 80%, while N fertilization – only by 35%.

An important task now is to improve the existing variety and breed new varieties with the improved, economically valuable characteristics. Therefore, studing the initial material for the selection of galega and working out the methodological foundations for selection process are of great significance. The aim of our work was to investigate the symbiotic polymorphism of galega plants and their selection for N_2 -fixing activity with a view to increase yields, seed production and land reclamation purposes.

The collection of galega specimens was studied in the trial fields of the Estonian Research Institute of Agriculture in 1984...1987. The institute is situated in the northern agroclimatic district of Estonia, approximately 15 km from Tallinn. The weather was characteristic to the given district during the research period. Compared with the average of several years, the trial years can be characterised as follows: 1984 and 1985 – cold, with excess moisture; 1986 – moist, relatively warm; 1987 – cold, with excess moisture.

The specimens were obtained mostly from the former All-Union Institute of Plant Production, but also from the other experimental establishments from the previous Soviet Union. During the investigation period we studied 17 specimens of galega. The geographical origin of specimens was the following: 6 from Krasnodar territory, 2 from Stavropol area, 2 from Armenia, 1 from Georgia, Mordovia, Komi, Moscow and Leningrad districts. The collection contained 6 local and 11 wild specimens (Table 1).

Table 1. *The collection of galega specimens studied in Estonia (1984...1986)*

No	Specimens	Origin of specimens	Year of the collection of seeds	Reproduction
9494	wild	Krasnodar territ., Maikop	-	1979
11911	wild	Armenia, Loori hayfield	-	1978
13306	wild	Krasnodar territ., forest	1932	1979
16568	wild	Stavropol, Železnovodsk	1933	1979
16586	wild	Stavropol, Pjatigorsk	1933	1970
16942	wild	Krasnodar, Toply kluts	1934	1979
17185	wild	Krasnodar, Bely kluts	1934	1979
17188	wild	Krasnodar, Beloretsensk	1934	1972
24864	wild	Krasnodar, Suntuk	1935	1979
28670	wild	Armenia, Sarvangai	1950	1979
33157	wild	Krasnodar, Tulski distr.	1953	1979
33784	local	Moscow distr., Institute of Fodder Crops	1974	1978
39342	local	Mordovia, Research Station	1974	1981
44240	variety Gale	Estonian Research Institute of Agriculture	1983	1983
46800	local	Komi, Ural Research Centre	1982	1982
46801	local	Georgia, Bakurian Botanical Garden	1981	1981
46802	local	Leningrad distr., Kirisi	1983	1983

Specimens were planted by seedlings (50×50 cm) in 4 replications. There were two variants used for investigation: one for green plant material, the other for seed. Totally 1640 individual plants were studied, 40 in each specimen. The registered variety Gale was used as a standard. In order to study and pick out the valuable genotypes from the population of the variety Gale, it was planted by seedlings (100×100 cm) in the nursery garden. Before sowing the seeds were inoculated with *Rhizobium galegae*, containing the active strain 740 R.

The breeding program included studing of intraspecific variation, initial material for breeding and search of possibilities for increasing the symbiotic efficiency of galega. The nitrogen-fixing activity was determined in three independent microvegetative trials (under sterile conditions) by using the acetylene reduction assay (Hardy et all., 1968), 1145 plants were screened.

Research of specimens by the basic selection parameters

There were significant differences both between years and specimens **in the lenght of growing period** and in that of development stages. The beginning of growth in spring was 4...6 days earlier in case of local specimens from Mordovia (k-39342), Komi (k-46800), the variety Gale from Estonia (k-44240), from Moscow (k-33784) and Leningrad districts (k-46802). Among wild specimens the ones from Krasnodar (k-9494) and Stavropol (k-16586) territories had an early emergence. According to the duration of vegetation period, the specimens were divided into groups. Wild specimens from Krasnodar (k-24864, 33157, 13306) and Armenia (k-11811) had a short vegetation period (93...95 days). The variety Gale (k-44240), the local varieties from Komi (k-46800), Mordovia (k-39342), Moscow (k-33784) and Leningrad (k-46802) districts, and the wild specimens from Krasnodar (k-17185, 17188, 9494) and Stavropol (k-16586) territories had a medium-long vegetation period (96...99 days). A longer period (100...103 days) was characteristic to the local specimen from Georgia (k-46801) and of wild specimens from Krasnodar (k-16942) and Stavropol (k-16586) territories.

As to **the height of plants** in the sowing year, the local specimens from Komi (k-46800) and Mordovia (k-39342) exceeded considerably that of the standard variety Gale (37±3.3 cm). On the same level with the standard were the specimens from Moscow (k-39342) and Leningrad (k-46802) districts. The wild specimens from Krasnodar (k-11811, 13306, 16942) and the local specimens from Georgia (k-46801) were considerably shorter. The height of plants on the 20th day after the beginning of vegetation varied in 1985...1986 between 44 and 68 cm. On the same level with the standard (63...68 cm) were the local specimens from Mordovia (k-39342), Komi (k-46800), Moscow (k-33784) and Leningrad (k-46802), the wild specimens from Stavropol (k-16586, 16568) and Krasnodar (k-16942) territories. As to the height before the first cut, there were no considerable differences. On the average of years the local specimens from Leningrad (k-46802), Komi (k-46800) and Mordovia (k-39342) were on the level of the standard variety (102...105 cm). In our trials the height of plants on the 20th day after the first cut reached 41...57 cm. The tallest (55...57 cm) were the local specimens from Leningrad (k-46802) district and the wild specimens from Armenia (k-28670). On the same level as the standard variety were the local specimens from Moscow (k-33784), Mordovia (k-39342), Komi (k-46800), Georgia (k-46801) and the wild specimens from Stavropol (k-16586, 16568) and Krasnodar (k-9494, 16542) territories. Before the second cut, a group of local specimens from Mordovia (k-39342), Komi (k-46800), Leningrad (k-46802) and Moscow (k-33784), as well as the wild specimens from Armenia (k-28670, 11811), Krasnodar (k-18185, 16942) and Stavropol (k-16586) were taller (63...75 cm).

The number of stalks per m^2 varied in the year of sowing between 17 and 36, the average number being 23.7 stalks/m^2 The wild specimens from Krasnodar (k-9494, 17188, 24864, 33157, 17185) and Stavropol (k-16586) territories, the local specimens from Leningrad (k-46802) and Komi (k-46800) had in the sowing year a thick stand of stalks, i.e. 25...36 stalks/m^2. In the following years the stand of stalks was thickest, i.e. 46...57 stalks/m^2, in case of the specimens from Mordovia (k-39342), Komi (k-46800) and Leningrad (k-46802), as well as the wild specimen from Stavropol (k-16568) territory. On the standard level (42...45 stalks/m^2) were the local specimens from Moscow (k-33784) and the wild specimens from Krasnodar (k-17188, 17185, 13306) territory and Armenia (k-28670).

The percentage of leaves in the sowing year was 46...71%. The percentage of leaves was highest on the local specimens from Leningrad (k-46802), Komi (k-46800), Mordovia (k-39342) and the wild specimens from Krasnodar (k-33157, 17185, 24864, 17188, 13306) and Stavropol (k-16568) territories. The highest percentage of leaves (48...56%) in 1985...1986 was on the wild specimens from Armenia (k-28670, 11811), Stavropol (k-16586, 16568) and Krasnodar (k-33157, 9494, 13306) territories. In the second cut all specimens had a high percentage of leaves (52...65%). This parameter was the highest on the specimens from Georgia (k-46801).

According to **the thickness of stalks** on the level of the 4th internode, the specimens could be divided into two groups. To the first group belonged the specimens with thin stalks, i.e. 3,5...4,0 mm in the first cut and 2.5...2.8 mm in the 2nd cut. These were the wild specimens from Krasnodar (k-9494, 24864, 16942) and the local specimen from Georgia (k-46801). The local specimens from Mordovia (k-33784), Komi (k-46800) and variety Gale from Estonia made up the 2nd group of specimens with thick stalks, i.e. 4.8...5.7 mm in the 1st cut and 2.9...3.3 mm in the 2nd cut.

Biochemical analyses indicated a difference in the dry matter content and in its composition (protein, ash, fats, crude fibre). In the year of sowing the content of dry matter varied between 19...26%. In the following years the dry matter content in the 1st cut was 18...26%, in the 2nd cut 28...34%. The green material, which was left after seed harvesting, contained 36...43% of dry matter. Of all samples the protein and dry matter contents were the highest on the variety Gale (k-44240) and the local specimens from Moscow (k-33784), Leningrad (k-46802) districts and Komi (k-46800) and Mordovia (k-39342).

By the **yield of fresh material** in the year of sowing, we picked out specimens which were able to give a yield of full value already in the 1st year. Their yielding ability was between 110...150 g/m^2, which was 164...224% of the standard. To this group belonged the local specimen from Komi (k-46800), the wild specimens from Krasnodar (k-24864, 9494) and Stavropol (k-16586) territories and Armenia (k-28670). By the yield of fresh material (two cuts, average of three years), the specimens could be divided into three groups: the group of specimens with high yielding capacity, i.e. 1950...2332 g/m^2 (88...106% of the standard). To this group belonged all local specimens: from Estonia, Komi, Mordovia, Moscow and Leningrad (k-44240, 39342, 33784, 46800, 46802). The wild specimens from Krasnodar (k-9494, 33157) and Stavropol (k-16586) territories and the local specimen from Georgia (k-46801) made up the group of low productivity - 983...1316 g/m^2 (45...60% of the standard). All other specimens belonged to the group of medium productivity, 1483...1759 g/m^2 (67...80% of the standard).

By seed yields the best (33.2...42.1 g/m^2) turned out to be the variety Gale from Estonia (k-44240), the local specimens from Mordovia (k-39342), Komi (k-46800), Moscow district (k-33784) and the wild specimens from Krasnodar territory (k-24864, 17185). The trial years (1985...1987) were on the whole favourable for seed production.

As to **the winterhardiness**, the galega specimens differed considerably. The main selection for winterhardiness took place in the very cold winter of 1984...1985. The most winterhardy specimens (92.5...92.8%) were the variety Gale from Estonia (k-44240) and the local specimen from Mordovia (k-39342). The local specimens from Komi (k-46800) and Moscow (k-33784), the wild specimens from Krasnodar (k-17185, 17188) and Armenia (k-28670, 11811) had a winterhardiness on the level of 70.0...82.5%. Overwintering was bad (40...55%) in the case of the specimens from Krasnodar (k-9494, 33157) territory. In the following winters of 1985...1986 and 1986...1987 the differences diminished, the average overwintering being 90.5...100%.

The characteristics of the best specimens of galega are given in Table 2.

Biometrical analysis of biological and morphological characteristics of galega

As it was shown earlier, the galega specimens studied in Estonian conditions, differed considerably in their morphobiological parameters. It is of primary importance to study the order of intraspecific organization of species, which facilitates the selection of initial material. Therefore, the aim of the next stage in our research was to systematise the information about the genetic polymorphism of galega by the basic morphobiological parameters.

The data about the individual variability of basic morphobiological parameters of galega specimens, studied in the field conditions in 1984...1987, were grouped on the basis of geographical origin of plants. The studied specimens were divided into 5 groups, being evolutionally formed in different geographical conditions: I – Krasnodar, II – Stavropol, III – Armenia, IV – Georgia, V – Moscow.

__Table 2.__ Characteristics of the best specimens of galega studied in Estonia in 1984...1987

No	Speci-men	Origin	Winter-hardi-ness, %	Fresh material 2 cuts, kg/m^2	Number of stalks per m^2	% of leaves	Height of stalks, cm		Seed yield, g/m^2	Dry matter content,%	Crude protein content,%
							1st cut	2nd cut			
44240	Variety Gale	Estonia	93	2.21	44.7	46.5	108.3	69.3	31.5	25.8	20.8
39342	Local	Mordovia	93	2.33	56.5	46.1	102.0	71.3	36.2	21.5	21.6
46800	Local	Komi	83	1.98	53.3	47.0	104.7	71.3	34.0	25.0	20.6
33784	Local	Moscow distr.	75	2.17	42.3	45.8	101.3	72.0	33.2	25.0	22.4
17185	Wild	Krasnodar territ.	80	1.76	46.7	47.7	96.7	65.7	34.0	24.5	19.2
46802	Local	Leningrad distr.	65	1.95	45.7	40.1	105.0	74.0	25.7	25.5	17.6

Within the groups the data about biometrical variability of populations were put together and standardised. The parameters inside the groups were aggregated into one parameter G. For that different functions were used which expressed the dimension of all characters averages under G1 and G2 on different groups in equal system of XY coordinators.

Bigger differences on horizontal level have group centres from Krasnodar (1.25) and Moscow (-0.20). On vertical level the group of populations from Armenia (3.12) was different (Table 3).

Table 3. *Cluster analysis of geographical groups of of galega specimens*

Groups	Origin of specimens	Function X_{G1}	Function Y_{G2}
1	Krasnodar	1.25	-0.09
2	Stavropol	0.20	-0.98
3	Armenia	1.14	3.12
4	Georgia	-0.03	-0.84
5	Moscow district	-0.20	0.18

The first and second group presented wild specimens which had been collected in the foothills of the North Caucasus, the Armenian group presented wild specimens from the mountains of Armenia, the Georgian specimens were obtained from the botanical garden of Georgia. The Moscow group included specimens obtained from the seeds of the All-Union Institute of Fodder Crops.

Table 4 gives the comparison of the group of wild specimens from the North Caucasus (k-9494, 13306, 16942, 17185, 17188, 24864, 33157, 16568, 16586) and that of specimens (k-33784, 39342, 44240, 46800, 46802), the initial material of which has passed selection of many years in the conditions of Moscow district.

Analysing the data concerning the beginning of growth period in spring, we could distinguish considerable differences between the two groups. In the group of specimens, originating from Moscow district, early emerging plants were dominating, whereas the majority of wild specimens from Krasnodar territory was characterized by a later emergence. As to the dates of flowering, early flowering plants were more characteristic of the wild specimens of Krasnodar.

Comparing the coefficients of correlation, we distinguished considerable differences in several parameters between the two groups. These differences indicate a genetic determination in the groups (Table 5).

The group of specimens from Armenia was not presentable for futher statistical analysis. But our data about this group could still help to prove the theory of mr. Simonov about the existence of a mountainous ecotype of galega in the vicinity of Lori.

The analysis of the results showed that the described specimens were representing the North-Caucasian, the mountaineous Trans-Caucasian (by Simonov Lorian) and the Moscowian ecotypes.

In order to determine the range of variability of several morphological parameters of galega in its natural growing environment, and in order to select out the most valuable genotypes, we studied the Idzhevaiski district in Armenia, the Maikop and Apseron districts in Krasnodar territory. All in all, we described 12 cenopopulations of galega in their generative state. Such parameters as the height of generative stalks, the number of internodes on the stalk, the length of leaves were characterized by low variability (v%) – 7.8...17.6%. The thickness of stalks was characterized by medium variability - 20.9...21.4%. More variable (35.2...45.7%) were the parameters of the generative parts of stalks – the number of pods in cluster and the length of cluster. On the whole the variability of parameters was lower in the natural growing environment than in the conditions of introduction.

Table 4. *Comparison of morphobiological parameters of two groups of galega: wild specimens from the North Caucasus and introduced specimens from Moscow district*

Parameters	Results					
	$x \pm M_X$	t-st	lim	σ	V %	t-st
Beginning of growth in spring, points	1.35±0.06 / 1.82±0.07	5.11**	1-3 / 1-3	0.56 / 0.64	42±3.2 / 35±2.7	1.68
Height at 1st cut, cm	119.1±1.76 / 107.6±1.72	4.67**	66-160 / 70-140	16.6 / 17.1	14±1.1 / 16±1.2	1.23
Number of stalks per plant	24±0.93 / 23±1.25	0.64	2-54 / 2-113	8.81 / 12.36	37±3.1 / 53±4.1	3.12**
Weight of fresh material,1st cut, g	946.6±39.51 / 640.2±33.96	5.87**	100-2000 / 25-1820	374.9 / 336.2	40±3.0 / 53±4.1	2.55**
Weight of fresh material, 2nd cut, g	491.1±21.55 / 398.2±18.70	3.25**	150-1360 / 50-980	204.4 / 185.1	42±3.2 / 46±3.6	0.83

Note: Numerators indicate the results of the Moscowian group, denominators of North-Caucasian group
* $p< 0.05$ ** $p< 0.01$

Table 5. *Comparison of biomorphological parameters of North-Caucasian and Moscowian groups of specimens*

Comparable parameters	Coefficients of correlation		
	North-Caucasian group	Moscowian group	t-st
Beginning of vegetation – beginning of flowering, points	-0.38**	-0.15	1.59
Beginning of vegetation, points – Height on the 20th day of vegetation, cm	-0.24*	-0.51**	1.86
Beginning of flowering, points – Weight of green material, 1st cut, g	0.1	0.24*	0.86
Beginning of flowering, points – Thickness of stalks, 1st cut, mm	0.03	0.31**	1.87
Height of 1st cut, cm – Weight of green material, 1st cut, g	0.46**	0.44**	0.16
Height of 1st cut, cm – Weight of 2 cuts, g	0.39**	0.42**	0.23
Weight of 1st cut, g – Beginning of vegetation	0.33**	0.01	2.13*
Height of 2nd cut, cm – Height on the 20th day after cut	0.06	0.38**	2.18*
Number of stalks – Weight of 2 cuts, g	0.19	0.68**	4.08**
Weight of 1st cut, g – Number of stalks	0.44**	0.66**	2.07*

* $p < 0.05$ ** $p < 0.01$

5.2. Evaluation and perspectives of the selection of fodder galega

The ecological and economic laws give many important arguments in favour of developing the ecological approaches in plant production. An increasing role of fodder crops in agriculture demonstrates a necessity to use bioenergetic criteria in plant breeding to increase efficiency of utilisation of natural resources by plant. The beneficial interactions between plants and microbes are of high importance for sustainable agriculture.

A domination of symbiotrophic over combined type of nutrition may related to the fact that galega is a "young" crop, which does not have a prolonged breeding history. A domination of the combined type of N nutrition over symbiotrophic one is typical for the "old" legumes crops (pea, lucerne), possibly due to an impoverishment of germaplasm in the "symbiotic" genes resulted from the plant cultivation under conditions of a sufficient combined N supply (Provorov, 1999). For improving symbiotic nitrogen fixation (SNF), breeding both interacting organisms – plants and nodule bacteria, is required.

Still, selection of fodder galega by the ability to symbiosis has not been carried out before. The aim of this work was to investigate symbiotic polymorphism of fodder galega plants and their selection for SNF activity with a view to increase fresh material and seed production and nitrogen fixation for agricultural and land reclamation purposes.

The individual variability of the fodder galega variety Gale by the N-fixing capacity in sterile experiment conditions (total 1145 plants were screened) was studied. The following *Rhizobium galegae* strains were used: commercial strain 740 and wild type strain 812. The N-fixing activity was determined in three independent micro-vegetative trials by using the acetylene reduction assay (ARA).

The breeding program included studying of intraspecific variation of the initial material for breeding and search of possibilities for increasing the symbiotic efficiency of galega.

Variety Gale possessed a high level of variability for symbiotic nitrogen fixation. For the acetylene reduction activity, the coefficient of variation of individual plants was 77.8-127.3%.

A pronounced skewness (As=+1.02...+1.69) for nitrogenase activity was revealed demonstrating that a majority of plants possessed a low level of nitrogen fixation. A similar asymmetric distribution of individual plants for nitrogen-fixing activity was revealed in alfalfa and sweet clover (Provorov, Simarov, 1990). As much as 14.8% of galega plants did not display a nitrogen-fixing activity (Fix^-).

Plants with maximal nitrogen-fixing ability (Fix^{++}) and good morphological parameters as well as Fix^- plants were picked out and replanted into the field conditions. The selected Fix^{++} plants when compared with Fix^- plants demonstrated a good development in the first year (Table 1), yielding ability and velocity of entering the generative stage at the second year (Table 2). A possibility to improve plant´s growth via selection for acetylene reduction activity was revealed previously in alfalfa (Barnes et al., 1984) and pea (Tikhonovich et al., 1987).

The Fix^{++}plants are included as an initial material for the further selection. The obtained data are used for developing the methodological basis for breeding new highly-productive and symbiotically active varieties.

Table 1. *Growth of fodder galega plants selected according to their nitrogen fixing activity in field trial (first year)*

Plant growth	Number of plants		
	Fix^{++}	Fix^-	Total
1 stalk (4-10 cm)	35	46	81
1-2 stalks (11-15 cm)	22	26	48
3-4 stalks, shrub (1620cm)	31	27	58
5-8 stalks densely shrugged (20-25cm)	29	10	39

Difference between Fix^{++} and Fix^- is significant (χ^2=9.90; P_o<0,05)

This method is most suitable at initial breeding stages for excluding genotypes with poor symbiotic nitrogen-fixing activity. Application of ARA at the next stages is more complex because it does not always correlate to the plant´s yield. The ARA is a more effective selection criteria when plants are screened from a defined plant population than from a collection of diverse genotypes.

Table 2. *Growth of galega plants differing in nitrogen fixing activity under field conditions (second year)*

Traits	Group of plants		t_{St} (P_0)
	Fix^-	Fix^{++}	
DM yield (air-dried) g/plot	2195 ± 250.5	4025 ± 463,5	3,52(P_o<0,05)
Height of plants, cm	54,8 ± 3,14	70,3 ± 3,89	3,10(P_o<0,01)
% vigorously developed plants	35,0 ± 7,54	62,7 ± 6,57	2,74(P_o<0,01)
% of plants in generative stage	52,5 ± 7,90	82,3 ± 5,34	3,12 (P_o<0,01)

This direction of investigation was initiated at the Estonian Institute of Agriculture and was supported in 1989-90 by the International program "Interbionitrogen 2000", All-Russian Research Institute for Agricultural Microbiology and in 1995-97 by the Estonian Science Foundation.

6. YIELDING ABILITY AND FEED VALUE

6.1. Yielding ability of pure stands

The first field trials at the Estonian Research Institute of Agriculture

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The establishment of the first field trials with galega succeeded in Estonia in 1972 because the specific bacterial preparation necessary for treating seeds had been worked out. The trials were established on sod-calcerous soil on limestone with pH 5.7…6.0 and P&K content in a 100 g of soil accordingly 8 and 14 mg. The seeds were sown with the row space of 21 cm, the sowing rate was 26 kg ha^{-1}, sowing depth 1…2 cm. Prior to sowing PK-fertiliser with application rate of P26K75 kg ha^{-1} was used. Such fertilising rate was also used in spring of every following year.

The plants developed slowly in the sowing year, being in September only 40…50 cm high. However, a thick and strong root system rich in rhizomes was formed. Its air-dry root mass was three times bigger than the weight of overground air-dry green material. In the spring of the second year of growth galega started to grow early. A number of shoots developed from the buds on underground stolons. Due to wide supply of food reserves the growth of plants was fast. The herbage yield was harvested twice – at the beginning of June and late in autumn.

The yielding ability of galega during the seven years of growth is given in Table 1. It shows that galega's plant cover is with a long utilisation period and it is rich in dry matter and crude protein. There was no decrease observed in the yielding ability even in the sixth and seventh year of growing – it was still 8…10 tons of dry matter per hectare.

In this trial the occurrence of other plants (weeds) in galega field was also studied. Of perennial weeds the most spread weed was common coach grass, which stolons did not damage under galega herbage but multiplied well. Considering this, common grass should be controlled prior to galega sowing. Galega field with normal density become almost free from annual weeds already since the second and third year of production.

Table 1. *The fresh material, dry matter and crude protein yields of galega in 1972…1978 (Raig, 1980)*

	Yielding ability t ha^{-1}		
Year	Fresh material	Dry matter	Crude protein
1972	24.5	4.9	1.0
1973	27.2	5.2	0.9
1974	34.6	9.3	1.7
1975	42.5	9.3	1.5
1976	51.7	9.6	1.7
1977	52.7	10.3	1.9
1978	43.1	8.2	1.3

Later on, starting from the eighth year of growth the fresh material yield of galega began to decrease slowly in the same field. For example, in the 13th year only 39% was received from the maximum yield.

Cutting time and frequency

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Galega`s persistence in plant cover depends a lot on cutting time and frequency. The choice of autumn cut is especially important, the yield of the following years and persistence are dependent on that.

Galega which is cut at the beginning of September starts to grow again, as a result of which the plant wearing out and is not capable to form hibernating organs – rhizomes and also overground parts. It causes an essential decrease in the yield of the following year, also inhibition of the development of plant. When cutting is carried out late in autumn, in October or beginning of November, there is no such kind of danger. The later cutting at the end of vegetation period in October had a favourable effect on galega growth and the spring yield of the following year. The average height of plants was 44.4 cm in spring of the following year, on May 26th. In case of earlier autumn cutting time the height of plants in spring was only 25.5 cm, almost a half less. Comparing with the earlier cutting time in autumn of the previous year, in case of later cutting in the following year as a total of two cuts, 10.7 more tons of fresh material and 2.0 tons more of dry matter were received. (Table 2).

Table 2. *The effect of cutting time in autumn on galega yield in 1978 (Raig, 1980)*

Autumn cutting time,	Cut	Fresh material yield ,	Extra yield		Dry matter yield	Extra yield	
1977		t ha^{-1}	t ha^{-1}	%	t ha^{-1}	t ha^{-1}	%
Early	First	16.0			2.7		
cut	Second	11.5			2.5		
12 Sept.	Total	27.5		100	5.2		100
Late cut	First	27.0			4.6		
(control)	Second	11.2			2.6		
23 Oct.	Total	38.2	10.7	139	7.2	2.0	138

The peculiarity of the handled galega`s growth and development should definitely be considered with. For receiving high yields from galega field, a special attention should be drawn to the choice of autumn cutting time, so that it would not influence plants` preparation for overwintering.

The more frequently the galega shoots are removed by cutting, the more the possibility of using sun energy for photosynthesis is restricted. In that case the majority of vegetation period is spent on aftergrowth, the optimum leaf area needed for photosynthesis will remain undeveloped. Frequent cutting also wastes out the underground stolons because the time for gathering supplies into them will remain short.

Comparison of galega`s yielding ability using two- and three-cut systems during one year is shown in Table 3. In a year it is possible indeed to get with three cuttings totally more yield, but later results showed the decrease in yielding ability of galega field when using this regime for a long time.

Table 3. *The effect of cutting frequency on galega yield during one year (Raig, 1980)*

Yield	Cutting time			Total yield	Extra yield compared to two cuts	
	14.-16.06	21.-25.07	27.-28.09		t ha^{-1}	%
			Cut for two times			
Dry matter	-	4.4	1.1	5.5	-	100
Crude protein	-	0.7	0.2	0.9	-	100
			Cut for three times			
Dry matter	4.3	1.3	1.1	6.7	1.2	122
Crude protein	0.8	0.2	0.2	1.2	0.3	133

Production dependent on development stage

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Dependence of production from development stage was determined in long-term trials carried out in 1986-1993. The plant was very persistent with a high yielding ability. The yielding ability was 8.5 to 10.5 tons of dry matter (DM) and 1.7 to 1.8 tons of crude protein (CP) per hectare with two cuts.

The field trials were established with fodder galega Gale in standard plot design with four replicates. The plots with the size of 12.5 m^2 were used for the 1st cut in six different development stages. The 2nd cut was taken at the 1st decade of October. Row space was 21 cm and sowing rate 30 kg ha^{-1}. The soil was sod-calcareous on limestone with the following characteristics: pH_{KCl}: 6.6…7.1, available P: 4.8…7.4 and available K: 12.5…17.4 mg per 100 g air-dry soil. Annual fertilisation: N0P26K75 kg ha^{-1}. Weeds were controlled in the year of sowing by herbicides containing 750 g l^{-1} MCPA as active ingredient. Application rate was 1.0 l ha^{-1}. Stubble of 10 cm was left after cutting in estimation of harvest.

Development of fodder galega in sowing year was slow due to its biological peculiarities. The height of plants in autumn didn't exceed 40 cm and the green herbage mass 2.3 t ha^{-1}. Beginning from the 2nd year of growth, fodder galega started approximately two weeks earlier in spring than red clover or lucerne. The rapid development in spring is also implicated by early flowering: it normally starts in the 1st decade of June. At this time the herbage yield of fodder galega is considerably higher than that of other forage legumes. The yield of fresh material was up to 30 t ha^{-1} already at the end of May.

The maximum DM yield of the 1st cut (7.4 to 8.8 t ha^{-1}) was obtained starting from the beginning of flowering until the end of flowering stages (Table 4). DM yield of the 2nd cut was on the average 3.5 t ha^{-1} and CP yield 0.60 t ha^{-1} when the 1st cut was made at budding and correspondingly 3.1 t ha^{-1} and 0.57 t ha^{-1} when the 1st cut was made at the beginning of flowering. The yielding ability of fodder galega was 8.5 to 10.5 tons of DM and 1.7 to 1.8 tons of CP per hectare with two cuts, if we considered the quality of forage and took the 1st cut at shooting or at the beginning of flowering.

Table 4. *Average DM yield of fodder galega herbage on the 1st cut at different development stages (starting from the 2nd year of growth) (Nõmmsalu, 1993)*

Development stage	DM yield, t ha^{-1}
Shooting	2.5
Budding	5.0
Beginning of flowering	7.4
Full flowering	8.7
End of flowering	8.8
Seed maturing	7.6
LSD .05	0.99

The good yielding ability of fodder galega became obvious in these trials. Fodder galega persisted over 7 years and gave stable and high forage yields.

The yielding ability of fodder galega on sod-calcareous and gley soils

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The yielding ability of fodder galega has been studied at Kuusiku, one of the regions with a harder climate in Estonia, since 1981. This crop has been grown on pebble sod-calcareous soil (pH_{KCl} 6.1-6.6; humus 2.8%; P&K content in 100 g of soil accordingly 6.4 and 16.6 mg) and on drained gley soil (pH_{KCl} 6.7-7.0; humus 8.5%, P&K content in 100 g soil accordingly 7.7 and 5.8 mg). In the year of sowing, fodder galega plants developed slowly at the early stage. Fields were infested with annual weeds. But already the second year of growth showed that fields of fodder galega were free of them. Long-term trials indicated that fodder galega was with a long persistence, its fresh material was rich in dry matter and crude protein and as a leguminous crop it showed quite a high seed yield. With fertilisation (P39.6K74.7) fodder galega gave relatively high yield with a two-cut system (June, September) for 8…10 years (Table 5).

Fodder galega was more fertile on sod-calcareous soil than on drained gley soil. As an average of 13 years of observation period (1982-1994) the dry matter yield of fertilised galega was 10.8% and seed yield 27.3% higher on sod-calcareous soil than on drained gley soil.

The trials also showed that in extensive cultivation (mineral fertilisers were not used and the yield was not removed from the growth place) the herbage of fodder galega remained thick and productive enough also in the 11th year (Figure 1). It indicates perspectiveness of fodder galega in recultivating mined areas (oil-shale and gravel pits).

Under long-term intensive cultivation the herbage of fodder galega thinned and yield ability decreased. Several plant species were found in association, more often common coach grass (*Elytrigia repens*), common nettle (*Urtica diocia*), fool`s-parsley (*Aethusa cynapium*), etc.

Table 5. *The yields (t ha^{-1}) of fresh material (FM), dry matter (DM), crude protein (CP) and seeds (S) of fodder galega in 1982…1999 (Viil, 1995)*

Year	Drained gley soil				Sod-calcareous soil			
	FM	DM	CP	S	FM	DM	CP	S
1982	44.71	8.94	1.47	0.07	43.20	8.74	1.48	0.06
1983	62.71	9.40	1.40	0.19	56.89	7.56	1.41	0.22
1984	39.98	6.00	1.29	0.17	43.77	6.11	1.47	0.18
1985	49.72	7.46	1.88	0.36	51.88	11.53	1.94	0.64
1986	38.27	5.97	1.21	0.27	38.73	5.84	1.12	0.34
1987	49.88	7.73	1.57	0.39	48.73	6.82	1.55	0.49
1988	40.00	7.12	1.26	0.36	39.27	7.72	1.30	0.50
1989	48.82	9.08	1.59	0.25	56.59	10.84	1.95	0.27
1990	23.91	4.52	1.01	0.12	26.11	5.22	0.99	0.18
1991	42.72	6.66	1.18	0.08	59.20	6.48	1.15	0.07
1992	26.67	4.88	1.02	0.19	36.50	6.16	1.00	0.20
1993	22.98	4.34	-	0.21	24.50	5.68	1.02	0.25
1994	23.71	4.65	-	0.15	30.21	5.59	-	0.17
1995	22.78	4.10	-	-	19.40	3.59	-	-
1996	20.92	3.69	-	-	16.39	3.31	-	-
1997	24.45	4.29	-	-	27.56	4.55	-	-
1998	33.12	5.21	-	-	31.52	4.99	-	-
1999	24.23	4.13	-	-	28.29	3.82	-	-

Soils did not have a significant part here. In the sowings of fodder galega it is possible to supress down severely the invasion of the mentinoned weed species, especially common coach grass (*Elytrigia repens*) with the help of herbicides. It enables to prolong the duration of use essentially (3…4 years). In the trials the more suitable herbicides turned out to be Agil 100 EC (1-1.5 l ha^{-1}) with 100 g/l of propaquizafop as active ingredient and Nabu (3-5 l ha^{-1}) with 200 g/l of sethoxydim as active ingredient. When using the last mentioned herbicide, a special wetting agency should be added. When using these herbicides for spraying after harvesting the seed yield, a damage of 75…85% of rhizomes of common coach grass (*Elutrigia repens*) occurred in the sowing of 6-7 years old fodder galega.

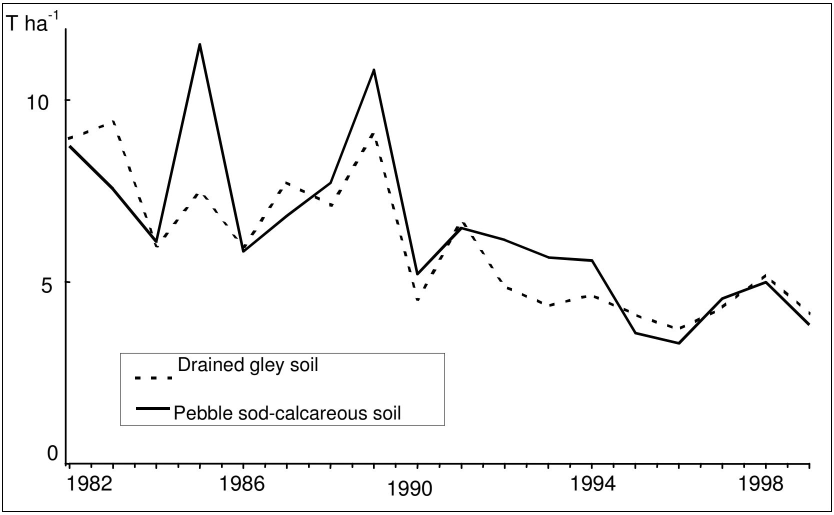

Figure 1. *The dynamics of fodder galega`s DM yield (t ha^{-1}) in the soils with different water regime at Kuusiku*

Yielding ability of fodder galega on sod-podzolic soil

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For the first time fodder galega was included in the trials of the Department of Grassland Husbandry and Botany of the Estonian Agricultural University in 1979 by Arnold Sau (1928-1983). At first its yielding ability was studied in mixtures with different grasses. In investigations carried out in 1995...1999 the effect of cutting regime on yielding ability of galega`s pure stands and their fresh material quality was examined, at the same time comparing it with other legumes grown in grasslands on Estonia.

At the end of May, 1995 a field trial was established on sod-podzolic soil (Podzoluvisol), which soil layer of 0...20 cm contained in autumn of 1995 before giving PK-fertilisers, 0.12% of N-total on the average, 1.95% of humus and 50 mg of P, 90 mg of K, 1450 mg of Ca and 100 mg of Mg per kg of soil; pH_{KCl} was 5.9...6.1. Galega variety Gale, birdsfoot trefoil Norcen (USA variety), red clover Ilte (late, tetraploid) and white clover Sonja (Sweden) were included into trial. Grass swards were established as pure stands. 9 different times of the first cut (i.e. it was cut in different development stages of plants) were comparison variants of cutting regime in this trial: starting *ca* from May 20 till the end of July, mostly with 7-day intervals. According to the time of the first cut, the number of cuts also turned out to be different during summer (2…4). Such establishment of a trial enabled to study the yield level of different species and nutritive value depending on cutting regime, also their sensitiveness to rather frequent cutting (4 cuttings = imitation of grazing). The invasion of not sown species into pure sowings and persistence of different species depending on time and number of cuts were investigated in the trial. Fertiliser input was $N_0P_{35}K_{83}$ kg ha^{-1} per year.

The climatic conditions of growing period (May...September) in the sowing year of grass sward (1995) and in the years of utilisation were characterised by the following data:

	1995	1996	1997	1998	1999	Average of many years
Average air temperature, C	14.8	13.7	14.6	13.9	15.2	13.3
Precipitation, mm	300	245	323	495	172	332
Occurrence of great water deficit in soil:						
period	5.07… 11.08 18.08… 27.09.	3.08… 6.09	21.07… 8.09	-	7.06… 29.09	-
number of days	79	35	50	0	115	-

On a very droughty sowing year (1995) significant yield was obtained only from red clover. About the years of utilisation it can be said that trial results show the reaction of galega and other investigated species to the number of different cuttings in extreme years: both in conditions of lasting water deficit (1996, 1997 and especially 1999) and abundance of soil water (1998). Cutting regime and weather conditions had a great influence on both the percentage of sown species in a corresponding pure sowing (Table 6, Figures 2...5) and the level of dry matter and crude protein yield (Table 7 ja 8, Figures 6 and 7) and content of crude protein (Table 9). At the same time in the summer of 1999 the drought was so severe in South-Estonia that these herbages where the first cut was made after June 22 did not give the second cut (i.e. until the middle of October there was nothing to cut). Heavy drought in soil lasted in 1999 almost for 4 months continuously (June 7...September 29).

From Table 6 and Figures 2...5 it can be seen that in this trial the most droughty species turned out to be white clover, which percentage in dry matter yield dropped down to 31% already in 1997, on the average (in 1996 it was 81%), raising later somewhere close to 50%. The persistence of birdsfoot trefoil turned out to be 4 years (the percentage in 1999 dropped down to 15%). The percentage of fodder galega in the herbage, on the contrary, remained until a very droughty year of 1999, near 70%. The share of the sown species in the yield was favoured by a smaller number of cuttings (except white clover).

The summarised yield data show that fodder galega, birdsfoot trefoil, and red clover had the increase in their dry matter yield together with the decrease in number of cuttings, i.e. in case of four and three cuts, as the average of 4 harvest years, accordingly 25, 23 and 7% less of dry matter (but considerably more protein rich) was received when in case of 2-cut system. White clover has the above mentioned relation vice versa: the dry matter yield of the herbage decreased with more rare cutting.

The influence of cutting regime on the herbage composition and yield was more obvious yet in 1996 and 1998 when it was possible to receive 4 cuttings.

Due to extraordinary strong and long-term drought, in the trial of 1999 it was not possible to stick to the planned cutting regime (from most plots only 1 cut was received), as a result of which it is complicated to use the yield data of 1999 for calculating the average yields of 4 trial years and comparing species and therefore it is more practical to observe them separately, so the effect of very heavy drought on the yield of different species will become evident more clearly.

Table 6. *The importance of legumes in pure sowings established in 1995.*

Annual number of cuts	Importance of sown species in DM yield, % of weight				
	1996	1997	1998	1999	Weighted mean
			Fodder galega Gale		
4	63	-	57	-	58
3	80	61	68	-	70
2	62	76	83	16	71
1	-	-	-	50	50
Mean	68	71	73	39	67
			Birdsfoot trefoil Norcen		
4	85	-	23	-	38
3	90	54	38	-	61
2	88	72	57	10	71
1	-	-	-	17	17
Mean	89	66	42	15	60
			Red clover Ilte		
4	99	-	70	-	81
3	99	90	80	-	90
2	99	96	82	56	91
1	-	-	-	68	68
Mean	99	94	78	63	88
			White clover Sonja		
4	-	-	60	-	60
3	82	40	53	-	57
2	86	23	43	47	48
1	74	-	-	53	61
Mean	81	31	54	51	56

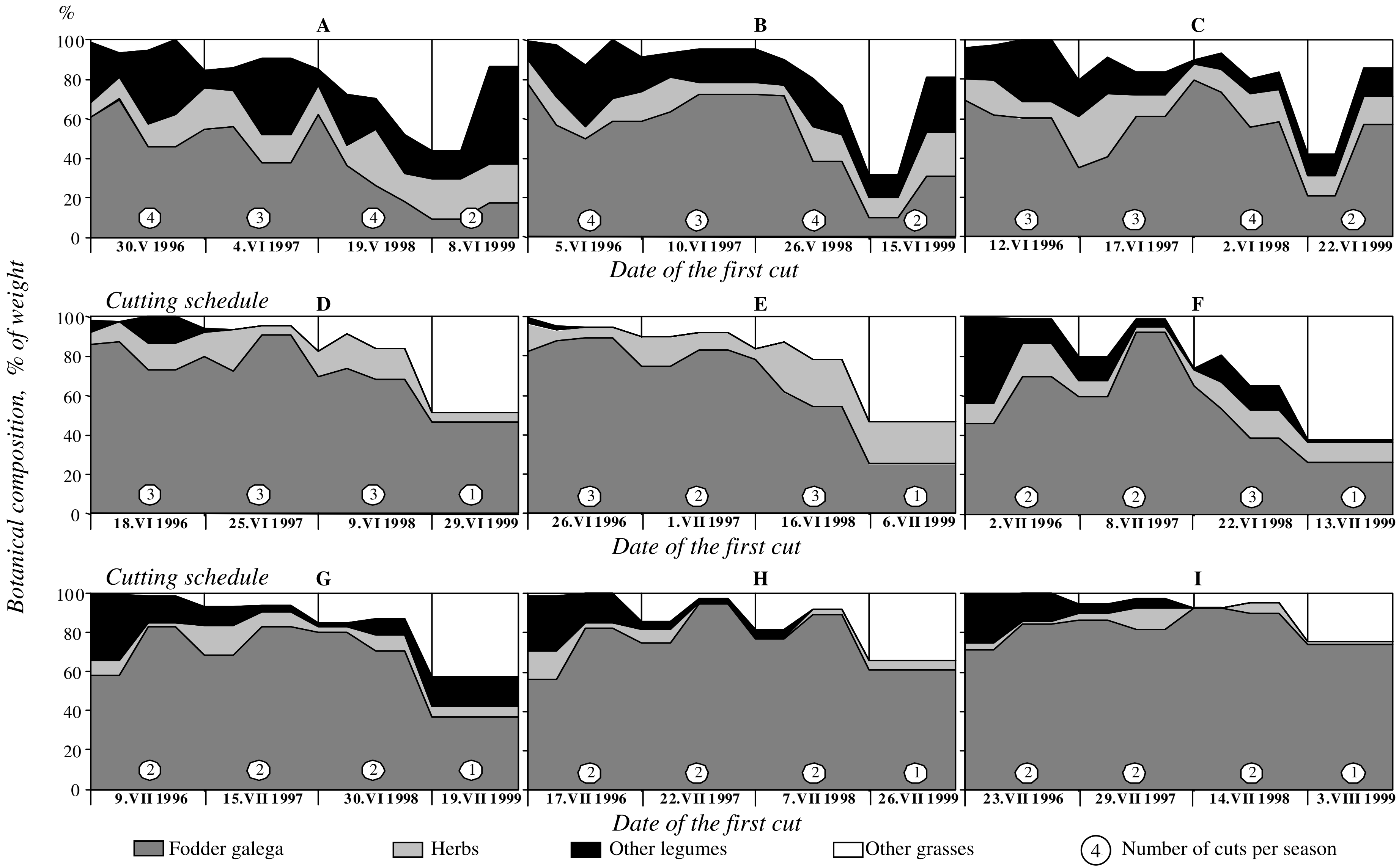

Figure 2. *Botanical composition of fodder galega pure sowings depending on cutting system (treatments A...I) in 1996...1999*

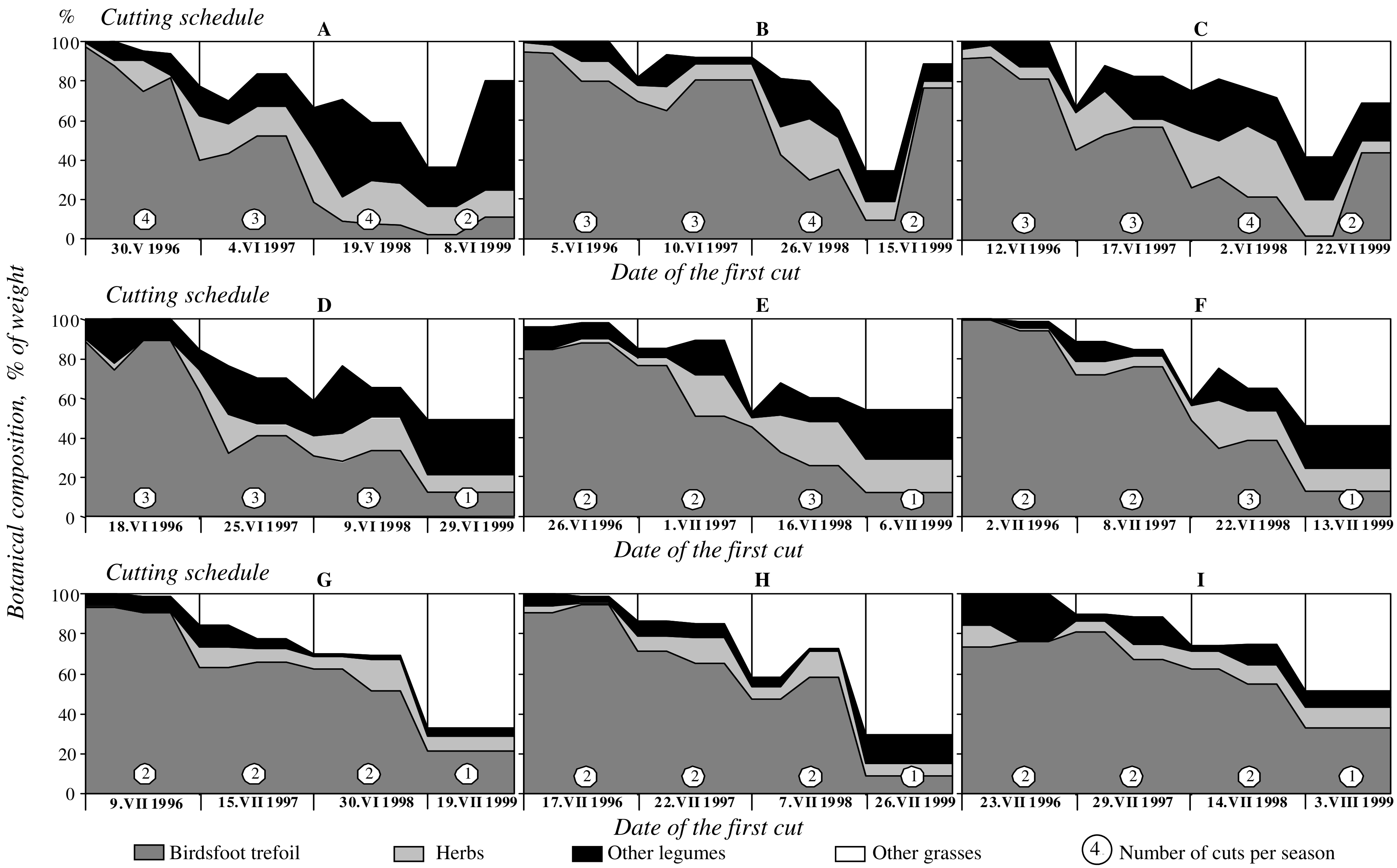

Figure 3. *Botanical composition of birdsfoot trefoil pure sowings depending on cutting system (treatments A...I) in 1996...1999*

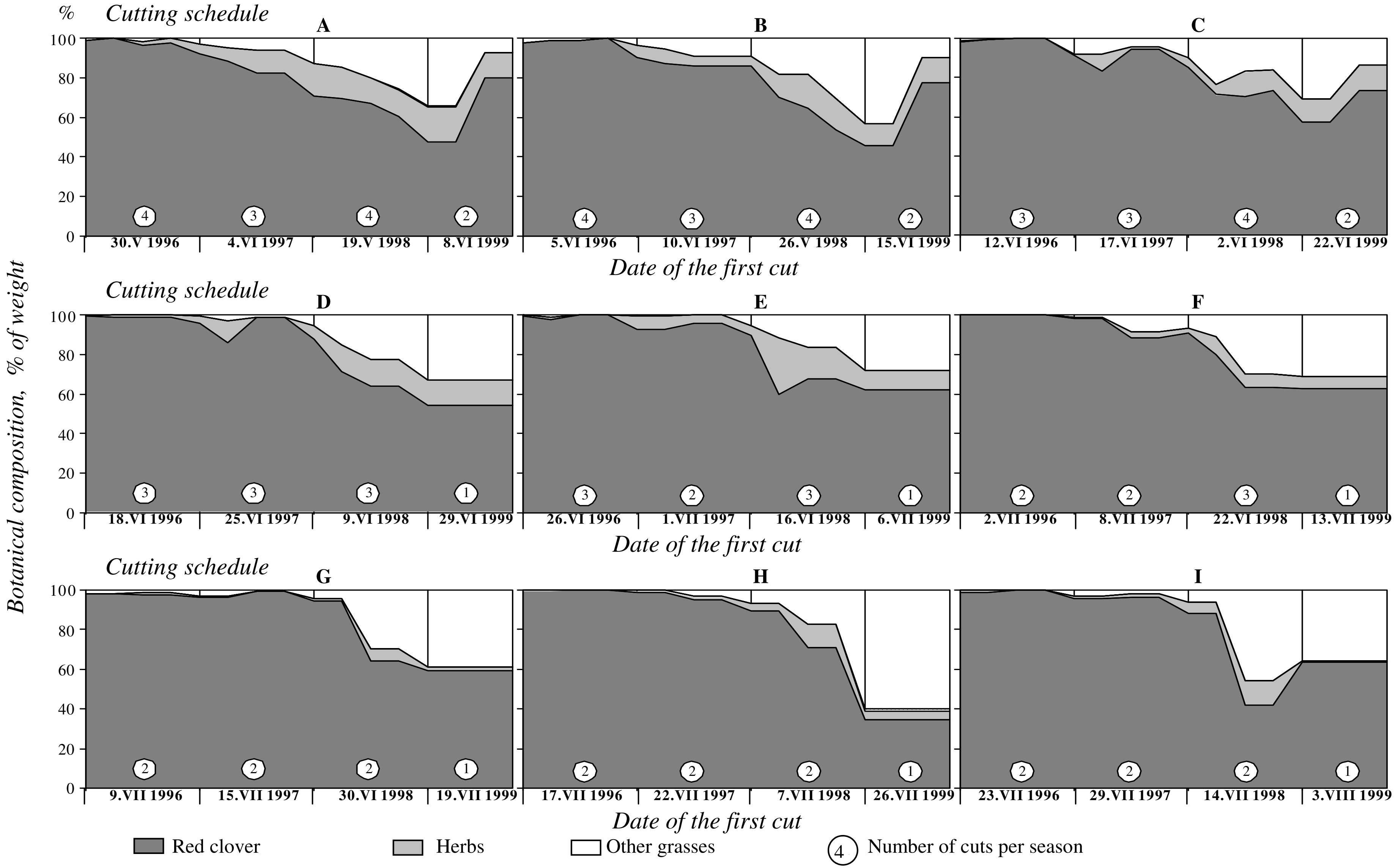

Figure 4. *Botanical composition of red clover pure sowings depending on cutting system (treatments A...I) in 1996...1999*

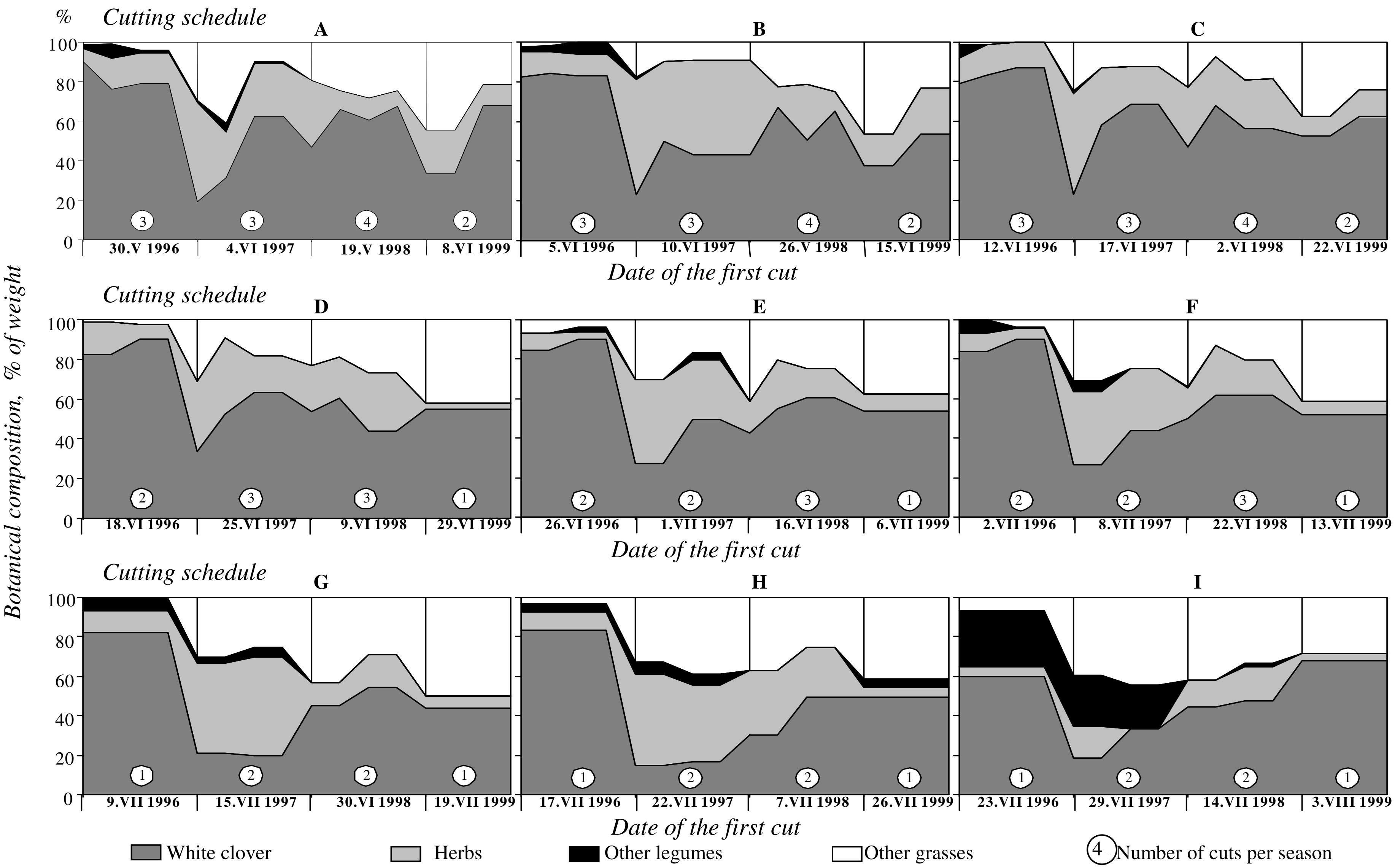

Figure 5. *Botanical composition of white clover pure sowings depending on cutting system (treatments A...I) in 1996...1999*

From the data (Table 7, Figures 6 and 7) we can see that dry matter yields of all herbages were evenly low in 1999 (2.1-2.7 t ha^{-1}), whereas with two cuts (the first cut in the stage of shooting or budding) on the average a little less (but much more qualitative) dry matter was received than using one-cut system (dry matter yield accordingly 2.12 and 2.36 t ha^{-1}).

As an average of two-cut regime (3 and 2 cuts), the studied species alined according to dry matter yield (t ha^{-1}) in 1996...1998 as follows: white clover Sonja 4.62 (100%), birdsfoot trefoil Norcen 5.26 (114%), fodder galega Gale 6.12 (132%) and red clover Ilte 6.66 (144%).

On the basis of crude protein yield (Table 8) the order of herbages as the average of cutting regimes (3 and 2 cuts) turned out to be the same as according to dry matter yield (t ha^{-1}): white clover Sonja 0.774 (100%), birdsfoot trefoil Norcen 0.818 (106%), fodder galega Gale 1.003 (130%) and red clover Ilte 1.109 (143%).

From the above-mentioned appears that dry matter and crude protein yields fluctuated by species percentally approximately to the same extent.

The content of crude protein in dry matter depended in the case of all species greatly on the number of cuts during summer: in more frequent cutting the fresh material was a lot more rich in protein when using one-cut and two-cut systems (Table 9). The percentage of sown legumes in the herbage in the present year had also a significant influence: when a legume started to fall off from the plant cover, the average protein content of herbage decreased, too.

Comparing with other trial years the content of crude protein in fresh material was the lowest in an extraordinary droughty year of 1999. The main reason was probably that due to constant water deficit in soil the action of nitrogen fixing nodule bacteria was supressed and the quantity of fixed nitrogen in root nodules remained small. The plants being in constant drought stress had also by the time of cut grown old physiologically (cell walls became lignified) and their protein content was decreased due to that.

Table 7. *Dry matter yield of legume stands depending on the cutting system in 1996...1999*

Annual number of cuts	Dry matter yield t ha^{-1}				
	1996	1997	1998	1999	Weighted mean
			Fodder galega Gale		
4	3.22	-	5.28	-	4.46
3	4.77	3.27	6.03	-	4.55
2	6.68	5.00	10.95	1.96	6.03
1	-	-	-	2.14	2.14
Mean	5.28	4.23	7.42	2.08	4.75
			Birdsfoot trefoil Norcen		
4	3.95	-	4.17	-	4.11
3	4.87	3.29	4.85	-	4.23
2	7.30	4.90	6.34	2.01	5.38
1	-	-	-	2.25	2.25
Mean	5.59	4.18	5.12	2.17	4.40
			Red clover Ilte		
4	5.59	-	5.84	-	5.75
3	7.05	4.34	6.92	-	5.92
2	8.09	6.43	7.13	2.59	6.24
1	-	-	-	1.98	1.98
Mean	7.19	5.50	6.63	2.18	5.37
			White clover Sonja		
4	-	-	8.49	-	8.49
3	3.89	2.82	7.62	-	5.08
2	4.19	2.83	6.35	1.93	3.68
1	4.03	-	-	3.07	3.39
Mean	4.04	2.83	7.49	2.69	4.26

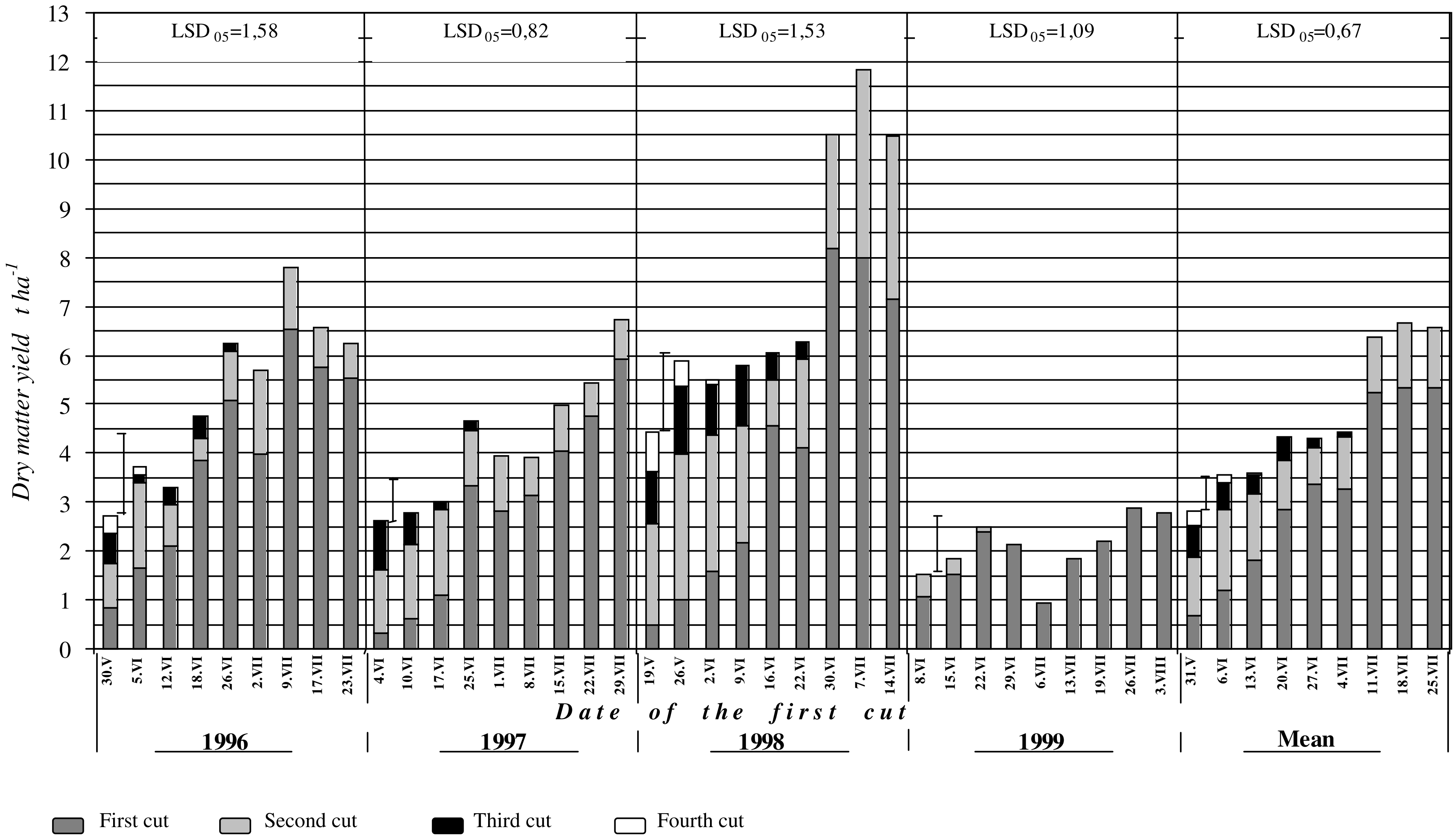

Figure 6. *Dry matter yield of fodder galega pure sowings depending on the date of the first cut in 1996...1999*

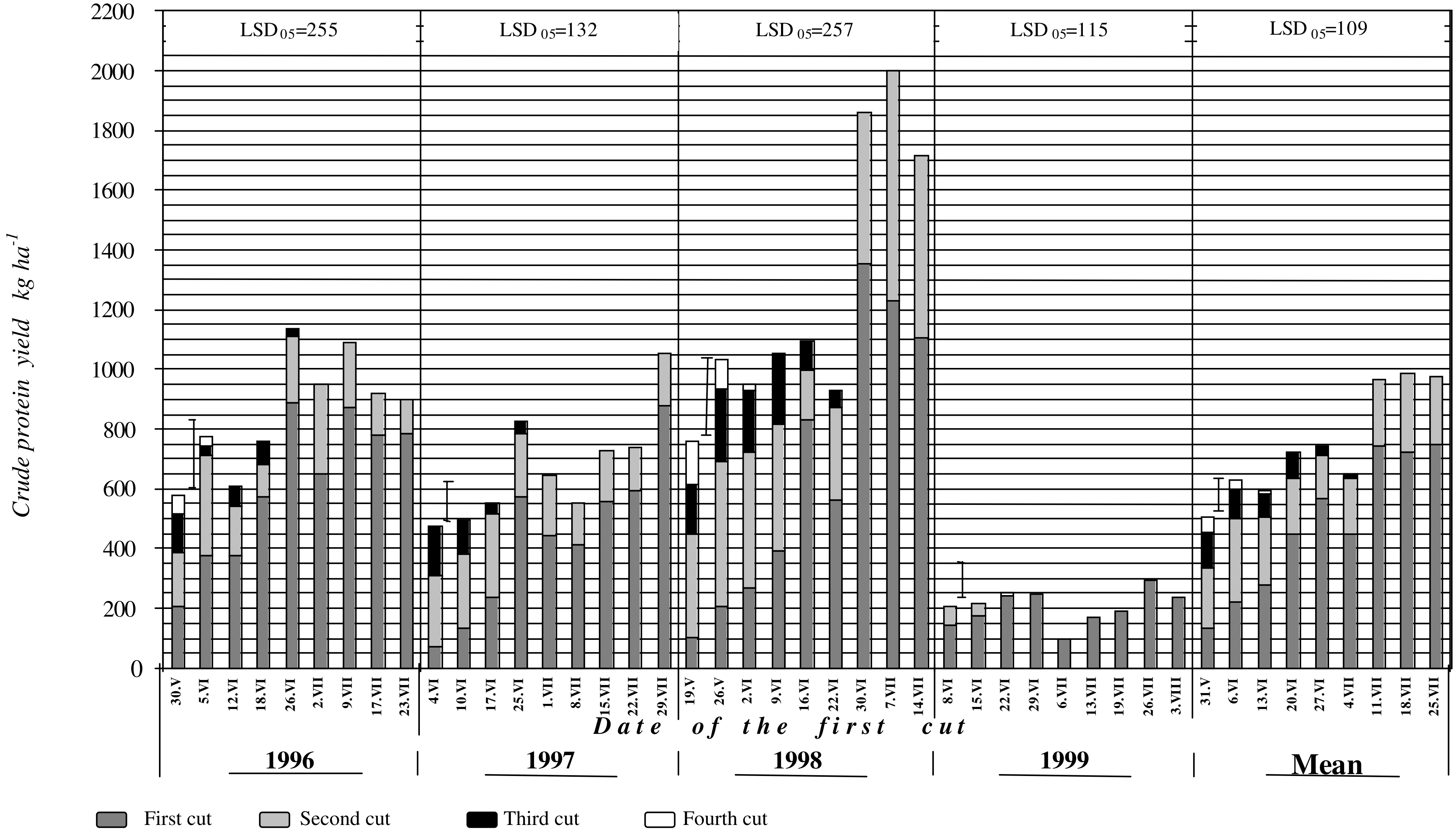

Figure 7. *Crude protein yield of fodder galega pure sowings depending on the date of the first cut in 1996...1999*

Table 8. *Crude protein yield of legume stands depending on the cutting system in 1996...1999*

Annual number of cuts	Crude protein yield, t ha^{-1}				
	1996	1997	1998	1999	Weighted mean
	Fodder galega Gale				
4	0.677	-	0.915	-	0.820
3	0.835	0.586	1.027	-	0.793
2	0.964	0.744	1.859	0.224	0.921
1	-	-	-	0.206	0.206
Mean	0.857	0.674	1.267	0.212	0.752
	Birdsfoot trefoil Norcen				
4	0.952	-	0.726	-	0.783
3	0.979	0.586	0.765	-	0.758
2	1.091	0.665	0.821	0.232	0.746
1	-	-	-	0.199	0.199
Mean	1.038	0.630	0.771	0.209	0.662
	Red clover Ilte				
4	1.334	-	1.162	-	1.231
3	1.362	0.855	1.277	-	1.134
2	1.132	0.892	1.134	0.378	0.901
1	-	-	-	0.254	0.254
Mean	1.253	0.875	1.191	0.295	0.904
	White clover Sonja				
4	-	-	1.585	-	1.585
3	0.863	0.414	1.332	-	0.824
2	0.833	0.314	0.888	0.262	0.537
1	0.683	-	-	0.364	0.470
Mean	0.793	0.359	1.268	0.330	0.687

Table 9. *Crude protein content in the yield of legume stands depending on the cutting system in 1996...1999*

Annual number of cuts	Crude protein content, % of DM				
	1996	1997	1998	1999	Weighted mean
			Fodder galega Gale		
4	21.0	-	17.3	-	18.4
3	17.5	17.9	17.0	-	17.4
2	14.4	14.9	17.0	11.4	15.3
1	-	-	-	9,6	9,6
Mean	16.2	15.9	17	10.2	15.8
			Birdsfoot trefoil Norcen		
4	24.1	-	17.4	-	19.0
3	20.2	17.8	15.8	-	17.9
2	14.9	13.6	12.9	11.5	13.9
1	-	-	-	8.8	8.8
Mean	18.6	15.1	15.1	9.6	15.0
			Red clover Ilte		
4	23.8	-	19.9	-	21.4
3	19.3	19.7	18.4	-	19.1
2	14.0	13.9	15.9	14.6	14.4
1	-	-	-	12.8	12.8
Mean	17.4	15.9	17.9	13.5	16.8
			White clover Sonja		
4	-	-	18.6	-	18.6
3	22.2	14.7	17.5	-	16.2
2	19.9	11.1	14.0	13.6	14.6
1	16.9	-	-	11.8	13.8
Mean	19.6	12,7	16.9	12.3	16.1

The influence of the time of the 1st cut and the number of cuts on crude protein yield (Table 8) was not so strong than in case of dry matter yield, and depended on legume species. The cutting system influenced most of all the crude protein yield of white and also red clover (it was the highest in four-cut utilisation), but in the sowings of fodder galega and birdsfoot trefoil this relationship appeared slightly. In case of fodder galega we can even talk about reverse tendency because in case of 2 cuts as the average of 1996…1999 somewhat higher crude protein yield was received than in case of using three and four cuts. The reason lies in the fact that dry matter yield of fodder galega increased relatively more in less often cutting, which guaranteed this species the highest protein yield when using a two-cut system.

Summing up, we can say that comparison of pure-sown stands of different legumes in 1996…1999 showed that the yielding ability of fodder galega during the first four years of growth was close to the productivity of red clover. Ignoring an exceptionally droughty year of 1999 the productivity of the studied legumes was in 1996…1998 as the average of cutting regimes (2…4 cuts) as follows:

	dry matter, t ha^{-1}		crude protein, t ha^{-1}	
fodder galega Gale	5.65	(100%)	0.930	(100%)
red clover Ilte	6.44	(114%)	1.105	(119%)
birdsfoot trefoil Norcen	4.96	(88%)	0.815	(88%)
white clover Sonja	4.80	(85%)	0.805	(86%)

The dry matter yield and crude protein yield of fodder galega formed accordingly 88% and 84% of the analogical data of red clover. Approximately by the same interval the pure stands of birdsfoot trefoil and white clover fell behind the yield level of fodder galega`s stand.

6.2. Feed value

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The feed value of the first and second cuts has been studied depending on cutting time in different development stages. The chemical composition of fresh herbage as well as leaves and stems were determined.

The soil where galega was growing was sod-calcareous on limestone (Rendzic Leptosol by the classification FAO-UNESCO) with the following characteristics: humus layer 15...18 cm, pH_{KCl} – 6.6...7.1, humus content 2.8...3.4%, total N - 0.20...0.24%, lactate soluble P – 4.8...7.4 mg and K – 12.5...17.4 mg in 100g air-dry soil. The fertilizer background was N-0, P-26, K-75 kg ha^{-1} in the autumn of every year.

Feed value in different development stages

Fodder galega can be characterized by quite a rapid **dry matter** (DM) accumulation in the fresh material during the development stages. On the average of years the dry matter content in herbage increased from 11.7% at shooting to 30.4% at seed harvest (Table 1). Dry matter content in leaves increased at the same time from 17.3 % to 29.7% and in stems from 5.9% up till 35.2%. The fresh material of fodder galega contained more dry matter already at the stage of flowering than other leguminous fodder crops in Estonia at the same stage.

Fodder galega is a valuable crop because of high **crude protein** content. The content was the highest in fresh material at shooting and budding – on the average 226...276 g kg^{-1} per DM (Table 1). Leaves contained 264…310 g kg^{-1} of crude protein and stems 106…261 g kg^{-1}. The crude protein content in herbage was at the beginning of flowering still 163 g kg^{-1} per DM. At that time leaves and stems contained accordingly 253 and 83 g kg^{-1} of crude protein. Green stubble which remained after seed harvest contained 116 g kg^{-1} of crude protein. At the same time galega leaves at seed harvest may contain up to 17.5% of crude protein.

The **crude fibre** content in the fresh material increased during the growth and development of plants. At early development stages – at shooting and budding – the crude fibre content was on the average 190...263 g kg^{-1} per DM, but at seed harvest already 323 g kg^{-1}. The crude fibre content in fresh material increased rapidly during the first development stages, from 190 g kg^{-1} at shooting to 283 g kg^{-1} at the beginning of flowering, later the increase was lower. Leaves contained 1.9...2.4 times less crude fibre than stems. During shooting the crude fibre content of stems was 228...302 g kg^{-1} per DM, by the time of seed gathering it had increased to 438 g kg^{-1}. The increase of fibre content in leaves was slower – from 123...150 g kg^{-1} per DM at shooting to 184 g kg^{-1} by the time of seed harvest. Thus, the crude fibre content in the herbage should be considered and the 1st cut of fodder galega should be made as early as possible, before stems lignify too much.

Table 1. *The content of dry matter (%), crude protein, crude fibre, crude fat, ash and N-free extractives (g kg^{-1} per DM) in the herbage of fodder galega at development stages (Nõmmsalu, 1994)*

Development stage		Dry matter	Crude protein	Crude fiber	Ash	Crude fat	N-free extr.
Shooting	x	11.7	276	190	98	28	408
	s	1.6	25	3	9	2	20
Budding	x	16.3	226	263	84	23	404
	s	3.5	32	23	10	4	33
Beginning of flowering	x	20.6	163	283	79	22	453
	s	3.5	16	17	9	4	33
Full flowering	x	23.6	156	292	68	22	462
	s	1.9	17	9	5	3	19
End of flowering	x	28.0	127	304	69	22	478
	s	1.2	20	12	6	2	17
Seed maturing	x	29.9	119	317	65	18	481
	s	0.8	11	18	4	3	9
Seed gathering (remained green stubble)	x	30.4	116	323	69	16	476
	s	1.5	20	20	5	2	8

The content of **ash** in the fresh material was from 98 g kg^{-1} per DM at shooting to 69 g kg^{-1} at the time of seed harvest. The content of **crude fat** varied from 28 g kg^{-1} at shooting to 16 g kg^{-1} at seed harvest, the content of **N-free extractives** was in the same period 404...481 g kg^{-1}.

The *in vitro* **dry matter digestibility** of fresh material, cut at shooting stage, was 66...71%, at budding 58...64%, at the beginning of flowering 57...61% and at full flowering 54...58%. The dry matter digestibility of green stubble remaining after seed gathering was 48...53%. The low dry matter digestibility of fodder galega from the beginning of flowering is due to the high crude fibre content in herbage and evidently also to the great proportion of indigestible crude fibre fractions. The decrease of dry matter digestibility is as fast as the increase of crude fibre content during the first development stages.

With advancing the age of plants the **phosphorus** concentration in fresh material decreased (Table 2). The average phosphorus content of 3.2...5.0 g kg^{-1} of DM in the period from shooting to the beginning of flowering corresponds to the P requirement in fodder.

Table 2. *The content of mineral elements (g kg^{-1} per DM) and carotene (mg kg^{-1} per DM) in the herbage of fodder galega at development stages (Nõmmsalu, 1994)*

Development stage		P	K	Ca	Carotene
Shooting	x	5.0	41.8	8.0	195.5
	s	0.6	3.2	1.2	41.1
Budding	x	3.8	33.6	8.0	166.5
	s	0.4	2.8	0.9	38.4
Beginning of	x	3.2	29.9	8.9	132.7
flowering	s	0.8	2.0	0.8	31.4
Full flowering	x	2.2	25.5	9.7	129.0
	s	0.5	2.1	1.1	23.7
End of flowering	x	1.7	25.2	10.0	113.3
	s	0.2	1.4	0.7	12.9
Seed maturing	x	1.3	22.9	10.7	107.0
	s	0.4	3.2	0.9	20.8
Seed gathering	x	1.1	18.4	11.5	75.7
(remained green stubble)	s	0.3	3.2	1.0	14.5

The content of **potassium** was high at shooting (41.8 g kg^{-1} per DM), but at later development stages it dropped rapidly, being at seed gathering 18.4 g kg^{-1}.

With the growth and development of plants the content of **calcium** slowly increased. The calcium content of 8.0...11.5 g kg^{-1} per DM from shooting to seed gathering exceeded the average Ca requirement in fodder.

It should be borne in mind that these contents of mineral elements in fresh material of fodder galega correspond to the soils of our trial fields. On different soils these contents could be expected to be slightly different.

The **carotene** content in fresh material was at shooting on the average 195.5 mg kg^{-1} per DM (Table 2), and it corresponds to a high-quality grass. The green material obtained at the stage of budding contained 166.5 mg of carotene per kg, which indicates a good quality.

The crude protein of fodder galega's fresh material contained 18 **amino acids**, among them all essential amino acids. The content of amino acids depended on development stage and decreased from shooting to seed gathering (Table 3).

The share of the sum of amino acids in crude protein was during different development stages between 74.3...89.6%, being higher during budding and beginning of flowering, and lower during seed maturing. The content of essential amino acids was quite high, their sum constituted 38...47% of the sum of all amino acids.

Estimating the value of protein, it became evident that the herbage of fodder galega contained much lysine, isoleucine, phenylalanine, tyrosine, valine and threonine. At shooting, budding and beginning of flowering, the amount of lysine in green material was very high. The contents of methionine, cysteine and tryptophane were quite low.

Table 3. *The average content of amino acids (g kg^{-1} per DM) in the herbage of fodder galega at development stages (Nõmmsalu, 1994)*

Amino acid	Shooting	Budding	Begin. of flowering	Full flowering	End of flowering	Seed maturing	Seed gathering
Asparagine acid	55.5	43.8	25.0	19.3	10.8	9.9	9.3
Threonine	8.8	8.6	7.0	6.6	5.1	3.9	4.3
Serine	8.5	8.1	6.7	6.2	5.1	4.1	4.1
Glutamine acid	20.4	19.0	16.0	14.4	11.7	10.1	10.4
Proline	19.7	18.8	15.9	15.2	12.4	10.8	10.8
Glycine	8.2	7.6	6.2	5.8	4.9	4.1	4.3
Alanine	9.8	9.1	7.1	6.9	5.7	4.8	5.1
Valine	11.4	11.1	8.9	8.3	6.6	5.5	5.5
Cysteine	1.3	1.3	1.1	0.8	0.6	0.4	0.3
Methionine	2.0	1.9	1.5	1.0	0.8	0.6	0.4
Isoleucine	8.3	7.9	6.9	6.7	5.2	4.5	4.5
Leucine	13.7	13.0	11.2	10.7	9.1	8.3	7.6
Tyrosine	5.8	5.9	4.9	4.3	3.2	2.6	2.6
Phenylalanine	10.1	10.2	9.0	8.4	6.5	5.0	4.9
Lysine	12.0	12.1	10.2	9.0	7.3	6.2	6.2
Histidine	5.2	4.7	3.9	3.1	2.5	2.2	2.0
Arginine	7.6	7.3	6.0	5.6	4.8	3.6	3.8
Tryptophane	1.4	1.4	1.0	0.8	0.6	0.3	0.3

Content of sugars. The sum of easily metabolisable sugars in fresh material was at shooting 93.0±29.0 g kg^{-1}, at budding 59.0±14.0 g kg^{-1} and at the beginning of flowering 39.0±10.0 g kg^{-1} per DM. Monosaccharides (glucose and fructose) constituted a major part of it, there were less oligosaccharides. The highest was the content of glucose.

The sugar and crude protein contents in fodder galega's herbage are unbalanced – too much crude protein and too few sugars. It is possible that there may arise a deficit of easily assimilable carbohydrates in fodder diets.

Content of alkaloids and toxicity. The question of toxicity arose, because another species from the genus of goat's rue (*Galega*) – *Galega officinalis* L. –, which originates from the same regions and was used as a herb and a fodder crop in Central Europe, contains alkaloids (galegine, vasicine) and can be toxic. The earlier alkaloid researches have been connected just with that species. Only some researchers have indicated in their works that the overground part of *G. orientalis* Lam. does not contain alkaloids, or contains them only by steps (Schreiber, Aurich, Pufahl, 1962; Köhler, 1969).

The galegine content in the overground parts of the *Galega orientalis* Lam. was determined at Helsinki University (Finland) by the method of thin-layer chromatography. The leaves, seeds and inflorescences of *G. orientalis* Lam. did not contain galegine (Virkajärvi et al., 1991).

Results of analyses, carried out in the Laboratory of Pharmacology of Helsinki University (by docent Laakso), showed that the content of vasicine in fresh material of fodder galega was at shooting 0,004 g kg^{-1} per DM, at budding 0,0016 g kg^{-1} and at the beginning of flowering 0,0014 g kg^{-1}. At the same time fresh material of *G. officinalis* L. contained during flowering 1,7 g kg^{-1} of vasicine per DM. It is obvious that such vasicine contents in the herbage of fodder galega are too low for causing any poisonings on agricultural animals. There have never been any poisonings with fodder galega in the feeding practice.

In co-operation with the Estonian Institute of Experimental and Clinical Medicine, we carried out toxicological studies on mice with the air-dry herbage of fodder galega, on the basis of corresponding special methods. The results showed that there was no toxicological influence.

In sowing year the development of fodder galega is slow due to its biological peculiarities and the height of plants in autumn does not exceed 30...40 cm. At the end of September the herbage contains on the average 20% of dry matter and 210 g kg^{-1} of crude protein, 230 g kg^{-1} of crude fibre, 85 g kg^{-1} of ash, 24 g kg^{-1} of fat, 2.7 g kg^{-1} of phosphorus, 28 g kg^{-1} of potassium and 12 g kg^{-1} of calcium per dry matter.

Feed value of the second cut

When the first cut is made in the beginning of June, towards the end of budding stage, or the beginning of flowering, the dry matter content in the fresh material of the 2nd cut increases from 19...20% at the beginning of August up till about 26...27 % in the second decade of October. Crude protein content in herbage decreases during this period on the average from 230 g down to 160 g kg^{-1} per DM and crude fibre content increases at the same time from 220 to 290 g kg^{-1} per DM. Crude fibre content in the 2^{nd} cut herbage during the regrowth of plants does not increases so fast as in plant`s development stages during the first cut and therefore there is no need for rush to take the 2^{nd} cut. It is also possible to cut still at the beginning of October where herbage contains 170…180 g kg^{-1} of crude protein and 260…280 g kg^{-1} of crude fibre per DM.

Phosphorus content decreased slowly together with ageing of plants from 3.0 g at the beginning of August to 1.4 g kg^{-1} per DM about 20^{th} of October. Potassium content in plants decreased, too – accordingly from 28 g to 20 g kg^{-1} per DM, but there was an increase in calcium content from 12 g to 18 g kg^{-1} per DM. Unlike the content of mineral elements in the herbage from the first cut, potassium content in plants of the 2^{nd} cut was not so high as during the first stages of development, but plants contained a lot more calcium.

Carotene content in fresh material was until the 20^{th} of October on the average from 135 to 185 mg kg^{-1} per DM. The content of amino acids was during the whole regrowth period at the same level as their quantity in herbage in the development stages of budding and beginning of flowering. The sum of metabolisable sugars fluctuated between 28 and 41 g kg^{-1} per DM. Content of sugars showed a small increase by the middle of October, especially the amount of oligosaccharides, which also indicated plants` preparation for the end of vegetation period.

Conclusion. The fresh material of fodder galega is of high nutritive value in case the 1st cut is made at shooting, budding, or at the beginning of flowering. At later development stages stems become too lignified, the fibre content in fodder increases and its digestibility decreases.

The fresh material cut at the stages of shooting and budding should be preferred, as it can be used both for green fodder and ensiling. The fresh material from the beginning of flowering stage is suitable for making hay. We can recommend to use for feeding even the green stubble which remains after seed gathering.

Using a two-cut system with the 1st cut at the budding or at the beginning of flowering and 2nd cut in the first decade of October, even the fresh material of the autumn cut is of good nutritive value. The autumn cut may be used also for green fodder or for making silage.

The fresh material of fodder galega is very suitable for ruminants, but can be used for feeding other domestic animals as well.

6.3. The yielding ability and feed value of mixtures

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Growing galega in mixtures with grasses enables to connect the need for nitrogen fertiliser with biologically fixed nitrogen in grasslands practically. The systems based on leguminous fodder crops are considered more environment friendly and sustainable in grassland cultivation. Production costs will be reduced most of all by costs on nitrogen fertilisers, because we don't need them. Species-rich grasslands give more stabile and higher herbage yields and they are more persistent than grasslands established with one-two species.

In mixtures, grasses are often more resistant and increase the stability of the plant cover, avoiding the appearance of weed centres in the field, which could often happen for example in pure stands of galega - if the field suffers from staying surface water or if it is with too acid reaction, it could cause the damage of galega plants.

On hilly landscape of South-Estonia the plant covers with galega and grasses have been helped to avoid erosion. When choosing species for mixtures, it also has to be considered with soil characteristics and moisture regime. Galega in mixture with more drought resistant grasses like cocksfoot, timothy or meadow fescue are more suitable for bald slopes of hills. For the hills` feet and marshy hollows and for valleys grasses tolerating more overmoisture are chosen for the mixtures, like smooth bromegrass, reed canary grass or meadow foxtail.

The yielding ability and feed value of galega and grass mixtures have been studied in Estonia both in the trials of Estonian Research Institute of Agriculture on sod-calcareous soil on limestone and in the trials of Estonian Agricultural University on sod-podzolic soil.

Mixtures on sod-calcareous soils

The first mixtures with galega were established in 1976. Then at first the whole field was sown with galega (sowing rate 20 kg ha^{-1}). The resowing was made with different grasses – cocksfoot (sowing rate 5 kg ha^{-1}), meadow fescue (4 kg ha^{-1}), smooth bromegrass or timothy (6 kg ha^{-1}) were used as components for mixtures. Phosphorous and potassium fertilisers were given before sowing. Some trial variants were fertilised additionaly with different amounts of nitrogen fertilisers.

The highest dry matter and crude protein yield were received from galega pure stands (Table 1). Since galega and grasses were sown at the same time, galega remained in the lower layer in sowing year because grasses developed and grew faster. As for development speed bromegrass, timothy and cocksfoot suited better for galega. It was also observed that by giving extra nitrogen fertilisers over 30 kg per hectare, the percentage of galega in the herbage decreased. Galega did not tolerate high nitrogen doses in mixtures.

In 1996 mixtures of galega and grasses were established on sod-calcareous soil on limestone, which was characterised as following: pH(KCl): 6.9-7.2, humus content 3.52-3.61%, lactate soluble P: 7.4-10.0 and K:16.4-18.3 mg per 100 g air-dry soil. Potato was the preceding crop. Total number of trial variants was 9 and the following grassland types were used: I – timothy Tika with the sowing rate of 100%; II – timothy Tika 50%+fodder galega Gale 50%; III – meadow fescue Arni 100%; IV – meadow fescue Arni 50%+fodder galega Gale 50%; V – cocksfoot Jõgeva-242 100%; VI – cocksfoot Jõgeva-242 50%+fodder galega Gale 50%; VII – perennial ryegrass Valinge 100%; VIII – perennial ryegrass Valinge 50%+fodder galega Gale 50%; IX – fodder galega Gale 100%.

Table 1. *The yielding ability (t ha^{-1}) of galega`s pure stand and mixtures with grasses (without using nitrogen fertilisers) (Raig, 1988)*

Trial variant	Yield									
	Dry matter					Crude protein				
	1977	1978	1979	1980	Mean	1977	1978	1979	1980	Mean
Galega	1.05	0.94	1.0	0.89	0.97	0.18	0.2	0.2	0.19	0.19
Galega+timothy	0.79	0.50	0.62	0.83	0.69	0.1	0.09	0.09	0.13	0.1
Galega+bromegrass	0.93	0.68	0.69	0.83	0.78	0.13	0.12	0.11	0.14	0.12
Galega+meadow fescue	0.64	0.45	0.66	0.87	0.66	0.13	0.08	0.12	0.17	0.13
Galega+cocksfoot	0.65	0.61	0.60	0.76	0.66	0.11	0.09	0.07	0.13	0.1

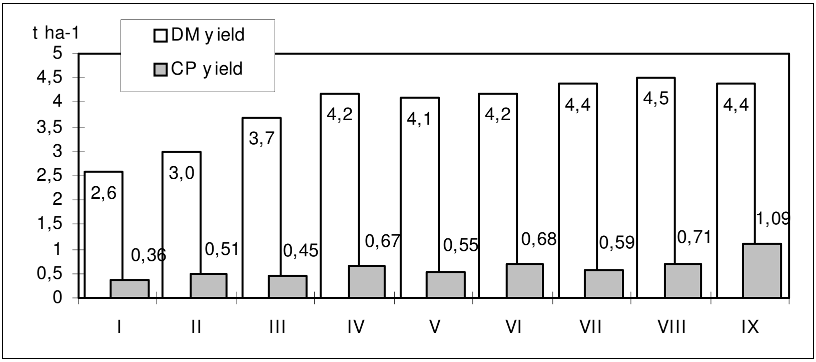
The sowing rates were the following: fodder galega 20 kg ha^{-1}, timothy 8 kg ha^{-1}, meadow fescue 33 kg ha^{-1}, cocksfoot 18 kg ha^{-1} and ryegrass 30 kg ha^{-1}.

Mixtures and pure stand of fodder galega did not get any nitrogen fertilisers, they received 40 kg ha^{-1} of phosphorus and 90 kg ha^{-1} of potassium every year, starting from the year of sowing. The pure stands of grasses were fertilised additionally with 35 kg ha^{-1} of nitrogen, they also received 35 kg ha^{-1} of phosphorus and 90 kg ha^{-1} of potassium.

In the first year of utilisation (1997) three cuts were harvested and in the second year (1998) two cuts. The amount of the yield, botanical composition of the grass and its quality were determined.

The grasslands established by fodder galega and mixtures of grasses gave, due to biologically fixed nitrogen, in the first two years of utilisation 3.7-4.4 tons of dry matter yield and 0.6-0.7 tons of crude protein yield per hectare a year (Figure 1). The annual grass yield of all mixtures was higher than the yield of the grassland established by the same grass species, which had received 35 kg ha^{-1} of nitrogen per year, but it did not overcame the annual yield of the pure stand of fodder galega, which was on 5.4 t ha^{-1} of dry matter and 1.2 t ha^{-1} as the average of two years of utilisation. The yields of galega mixtures with cocksfoot and meadow fescue were a bit higher than the other ones.

During the first two years of utilisation the yield from mixtures swards was still rather low. It was probably caused by extemely unfavourable weather conditions both in the first and the second year of use – in summer of 1997 the growth of the plants during the first and second cut fell at a very droughty period and the summmer of 1998 was considerably colder and more rainy than the average. Botanical composition of swards had the impact certainly too, because in the first two years of utilisation galega had not achieved its usual growth speed and its percentage in the mixtures for supplying grasses with nitrogen remained low. In case of pure stands of grasses 35 kg of nitrogen per hectare was not sufficient enough for getting regular yield, these species require certainly much more, the present fertilisation variant used by us was only for comparison purposes.



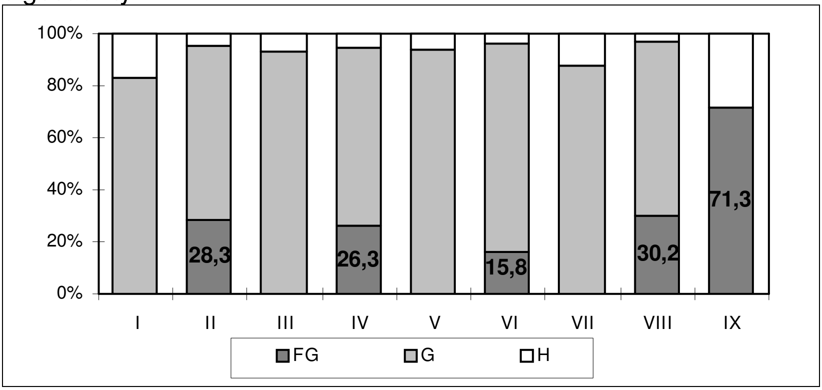
I - Timothy
II - Timothy/Fodder galega
III - Meadow fescue
IV - Meadow fescue/Fodder galega
V - Cocksfoot
VI - Cocksfoot/Fodder galega
VII - Perennial ryegrass
VIII - Perennial ryegrass/Fodder galega
IX - Fodder galega

Figure 1. *The annual yield (the average of two-year utilisation) of fodder galega-grass mixtures and pure stands of fodder galega and grasses (Nõmmsalu, Meripõld, 1998)*

On the average per two-year utilisation period the share of galega plants in botanical composition of mixtures` herbage was 20-29% per DM (Figure 2). It was less than could be expected by the sowing rate of mixtures' components. Due to its biological peculiarities, fodder galega did not achieve such growth speed during the first years of growth needed to compete with grasses. Most of all the growth of galega was supressed in the trial variant with cocksfoot. According to our earlier experiences fodder galega usually achieves the maximum growth speed for the starting its spring's growth and for regrowth period only on the third and the following years of growth. The analysis of the botanical composition of mixtures` herbages from the third year of growth showed that it contained galega a little more than compared to the herbages from the second year of growth. The swards of all mixtures contained less herbs than pure stands, thus they were more competitive in the fight with weeds.

The fresh material of the cuts harvested from grasslands established with fodder galega-grass mixtures and with pure stands of fodder galega was with high quality. As the average of all cuts per two-year utilisation period their yield contained 152-161 g kg^{-1} of crude protein, 248-270 g kg^{-1} of crude fibre and 80-119 g kg^{-1} of sugars per DM

(Table 2). Galega improved the yield`s quality first of all with higher crude protein and carotene content, grasses in their turn with higher content of sugars. The content of crude fibre in the yield of mixtures remained also lower compared to the yield both from grasses and from galega pure stands. All the above-mentioned factors caused better *in vitro* dry matter digestibility of the herbages from the mixtures. The yield harvested from galega pure stand had the best digestibility – 78.8%; of mixtures the yield harvested from galega-timothy and galega-ryegrass swards had somewhat better digestibility.



I – Timothy
II –Timothy / Fodder galega
III – Meadow fescue
IV – Meadow fescue / Fodder galega
V – Cocksfoot
VI – Cocksfoot / Fodder galega
VII – Perennial ryegrass
VIII – Perennial ryegrass / Fodder galega
IX – Fodder galega

Figure 2. *The botanical composition of the herbage (all cuts` average and per two-year utilisation; FG – fodder galega, G – grasses, H – herbs) from fodder galega-grass mixtures and pure stands of fodder galega and grasses (Nõmmsalu, Meripõld, 1998)*

The fresh material from fodder galega was the richest in crude protein and carotene – accordingly 219 g kg^{-1} and 156 mg kg^{-1} per DM. The fresh material of grasslands established by grasses contained crude protein only 107-121 g kg^{-1} and carotene only 89-112 mg kg^{-1} per DM. The fresh material received from pure stands of grasses was also more lignified compared to the ones received from mixtures or from galega pure stands – crude fibre content in grasses was 271-301 g kg^{-1} per DM.

Table 2. *The quality of herbage from fodder galega-grass mixtures and pure stands of fodder galega and grasses (all cuts` average and per two-year utilisation) (Nõmmsalu, Meripõld, 1998)*

	Grassland type	DM %	Crude protein g kg^{-1} DM	Crude fibre g kg^{-1} DM	Caro-tene mg kg^{-1} DM	Sugars g kg^{-1} DM	Digestibi-lity of DM *in vitro** %
I	Timothy	32,8	121	271	89	108	76,4
II	Timothy+ galega	27,6	161	248	141	84	76,6
III	Meadow fescue	30,4	107	284	95	129	74,1
IV	Meadow fescue+ galega	26,5	152	258	126	100	75,0
V	Cocksfoot	29,6	113	301	112	103	74,0
VI	Cocksfoot + galega	25,5	152	270	133	80	74,8
VI I	Ryegrass	30,9	111	274	112	146	74,9
VI II	Ryegrass + galega	26,1	159	249	150	119	75,8
IX	Fodder galega	22,8	219	269	156	57	78,8

* determined in the yield of the first year utilisation

The results of different trial variants show that from the given grasses not one can be preferred for growing in mixture with fodder galega. Somewhat better results as for the quality of the yield, after all showed the mixtures with timothy. The investigations on the yielding ability and the quality of swards based on mixtures with fodder galega require more profound approach.

Mixtures on sod-podzolic soil

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The object of ***the first trial*** (1979...1995) was to compare the productivity of legume-grass swards where different leguminous species were dominating with the grass-only swards which were fertilised with different annual rates of mineral nitrogen (0-400 kg ha^{-1} N during the vegetation period). The grasses (timothy, meadow fescue, smooth-stalked meadow grass and perennial ryegrass) were sown on trial plots on August 3, 1978, with sowing rate of 21.9 kg ha^{-1}. Legumes (fodder galega Gale, hybrid lucerne *(Medicago media*) Jõgeva 118, yellow lucerne *(Medicago falcata)* Saaremaa kohalik*,* white clover Jõgeva 4) were sown additionally in early spring of 1979 (April 5). Fodder galega was sown with the sowing rate of 30 kg ha^{-1}. Every year the whole trial area received 30 kg of P and 70 kg of K per ha. No N-fertilisers were given to leguminous mixed swards.

The trial was established on sod-podzolic soil (Podzoluvisol), the agrochemical characteristics of the arable soil layer (0...20 cm) were suitable for growing herbage plants: 2.25% of organic matter and 0.125% of total N, lactate soluble P – 95 and K – 130 mg kg^{-1}, pH_{KCl} was 6.0.

The yield was harvested according to the cutting schedule in trial scheme (Table 3). In the first two trial years the whole area of fodder galega was cut for three times. Starting from the third year of utilisation the two-cut utilisation regime was used. Since the 6^{th} year of utilisation (1984) the three-cut system was partly used and the times of the first and the second cut were also changed which caused the formation of the variants of new herbages (No 2…5). The change in the trial scheme enabled to study the optimum cutting times and frequency more exactly. For determination of all plants' phytomass the formation of total roots` material was also assessed. The root samples were taken and the roots were separated from the soil by washing with water. In 1979…1995 the trial area was irrigated to avoid yield losses caused by too dry soil (the number of irrigations during summer was 2...6 à 35 mm of water). The investigation period turned out to be rather long (17 years), which can be divided into three periods: I – years 1979-1984 (the main research period); II – years 1985-1990 (the following research period) and III – years 1991-1995 (additional research period).

Table 3. *Cutting schedule in the first trial in 1979...1995*

Herbage No & the first year of use	Time of cuts		
	I	II	III
1.* 1979	Beginning of full flowering stage	III decade of Sept. or I decade of Oct.	
2. 1984	Beginning of flowering stage	III decade of July	III decade of Sept. or I decade of Oct.
3. 1984	Beginning of full flowering stage	II decade of August	
4. 1986	Before flowering	III decade of July	III decade of Sept. or I decade of Oct.
5. 1987	In uneven-numbered years accordingly for the herbage No 1, in even-numbered years accordingly for the herbage No 2.		

* In 1979...1980 the herbage was cut 3 times

The development speed of fodder galega remained low in the sowing year. Its percentage in the herbage as the mean of sowing years` and per cuts was 25.6% (Table 4), being considerably lower than the share of different clover varieties (62.0%) and hybrid lucerne (38%) in the swards. It is obvious that the growth of galega plants during the first two years of utilisation (1979...1980) was negatively influenced by three-cut utilisation regime.

In 1981 it was started to use two-cut system due to which the percentage of fodder galega in the herbage increased as the average of 1983...1984 up till 71.3%. Fodder galega achieved the maximum share in the herbage by the 8th year of utilisation when its percentage reached 96.8%, having pressed out all sown grass species from the stand. During the following trial period the percentage of fodder galega in the herbage somewhat decreased but in the 17th year of utilisation its share still remained up to 76%. The received results show that in case of optimum cutting regime (i.e. in two-cut use, where the first cut is made at the beginning of flowering stage and the second one at the end of September or beginning of October) the competitiveness of fodder galega in grassland swards is very high.

Table 4. *The percentage of fodder galega in annual fresh herbages yield*

Trial years	No of herbage				
	1.	2.	3.	4.	5.
1979	25.6	-	-	-	-
1980...82	56.7	-	-	-	-
1983...84	71.3	64.5	54.8	-	-
1985...86	89.2	77.1	60.3	94.1	-
1987...88	76.7	66.1	66.2	71.8	72.4
1989...90	70.3	78.0	69.2	73.6	79.0
1991...93	77.0	51.0	41.2	66.0	59.9
1994...95	77.1	51.5	41.0	55.6	60.0

The only grass which fodder galega could not press out from the herbage was common coach grass. Its percentage reached up to 20% by the end of trial period. It also became evident that swards with domination of fodder galega in agroclimatic conditions of Estonia will not tolerate constant three-cut utilisation regime. The second cut in the middle of August, in case of two-cut system caused negative effect. The percentage of fodder galega in the herbage decreased to 30% by the end of trial period and an extensive invasion of dandelion into the herbage took place (over 30%).

As the only relevant source for nitrogen in rich in legumes swards is the symbiotically fixed nitrogen, the productivity of such herbages depends directly on the percentage of legumes in the herbage. The above-given regularity became evident also in this trial (Table 5). So the maximum dry matter and crude protein yields were received in the 7th and 8th and 11th and 12th years of utilisation (on the average respectively over 15 t ha^{-1} and 2,7 t ha^{-1}). The achieved level of vegetative production is close to maximum which can be expected in agroclimatic conditions of Estonia, since the potential yield of herbage plants is up to 16 t ha^{-1} of DM per year (Mäetalu, Karing, 1979). Three-cut utilisation regime and the change of the 1st and 2nd cut time had no positive effect on the yield. In these herbages (No 2…5) the yield decreased considerably by the end of the trial period. When comparing the productivity of the herbage where fodder galega is dominating, with swards where legumes with longer persistence are dominating (white clover, hybrid lucerne, yellow lucerne), it turned out that in maximum yield period fodder galega overcame the other swards considerably. Comparing the sward of fodder galega with the swards of pure grasses (which were fertilised with up to 400 kg ha^{-1} of mineral nitrogen), it appeared that 1 ha of fodder galega field fixed over 400 kg of nitrogen per year, being one of the most effective legume species in Estonian conditions.

Table 5. *The average annual yields of the herbages with fodder galega domination*

Trial years	Dry matter yield, t ha^{-1}					Crude protein yield, t ha^{-1}				
	No of herbage					No of herbage				
	1.	2.	3.	4.	5.	1.	2.	3.	4.	5.
1979	5.2	-	-	-	-	0,7	-	-	-	-
1980-82	6.6	-	-	-	-	1,2	-	-	-	-
1983-84	9.9	11.8	9.1	-	-	1,8	2,6	1,8	-	-
1985-86	15.3	12.0	12.5	14.3	9.4	2,9	2,6	2,4	3,0	-
1987-88	11.2	7.0	9.3	9.2	9.4	2,1	1,3	1,7	2,2	1,7
1989-90	15.3	13.2	11.1	12.0	13.9	2,8	2,6	1,9	2,3	2,8
1991-93	8.2	4.8	5.5	5.4	5.7	1,5	0,8	1,0	1,0	1,0
1994-95	13.8	5.1	5.4	5.4	8.6	2,7	0,9	0,9	0,9	1,7

For determination of the whole vegetative phytomass, in the first period of the trial the amount of dry mass of roots of fodder galega was also assessed. This reached on the average up to 5.3 t ha^{-1}, being below the root mass of grasses and lucernes. When studying the location of root mass it occurred that over 80% of it had concentrated in the surface layer (0...10 cm). From that the reason probably became evident why in vegetation period poor in precipitation the yield of the herbage rich in fodder galega had considerable decrease. In 1992 (the rain in May…Aug. only 101 mm) the 2nd cut practically did not grow and the herbage almost dried up, which still did not cause the damage of plants (dry matter yield was 7.7 t in 1992 and 9.6 t per ha in 1993).

For estimating the quality of the galegas' fresh material the content of crude protein, crude fat, crude fibre, crude ash and essential amino acids were determined in dry matter. The received data can be found in table 6. For comparison some quality data from some other herbages are also added.

Table 6*. The quality of the swards yield as the average of 1979...1987*

Composition of the sward	Content in dry matter, g kg^{-1}					
	crude protein	crude fibre	crude fat	N-free extrac. matters	crude ash	EAA*
1. Fodder galega+grasses	182	259	26	434	99	65.5
2. White clover +grasses	176	219	31	467	107	67.0
3. Hybrid lucerne+grasses	174	245	28	450	103	63.7
4. Grasses +N-0	123	258	28	492	99	43.5
5. Grasses +N-300	151	229	30	497	93	50.0

* EAA – essential amino acids

The data in Table 6 indicated that the quality of the fresh material received from the sward with fodder galega domination was high. It did not differ considerably from other legume-rich swards. The chemical composition of fresh material from swards showed that one of the most important indicators of yield`s quality – crude protein content, overcame the required level (140 g kg^{-1} per DM) in case of all swards with legumes, but the grass-swards needed to be given for that *ca* 250 kg ha^{-1} of mineral nitrogen per year. The comparable swards differed from each other considerably by amino-acid composition of protein, both by total content of amino-acids and the amount of essential amino-acids. Amino-acids (17 in all) formed 70…78% of crude protein. By the sum (g kg^{-1} in DM) of essential amino-acids (9 in all) the legume-grass mixtures overcame pure grass swards even on the background of 300 kg of N per ha by over 20%.

According to trial results we can conclude that the development of fodder galega is very slow in the first years of utilisation. Sown in mixtures with grasses, fodder galega achieves a share of 50% in the herbage on the second or third year of utilisation. The optimum number of cuts for fodder galega domination swards is two, whereas the first cut has to be made not later than in the beginning of flowering and the second cut at the end of September or beginning of October.

The grass sward with fodder galega domination achieves its maximum yielding ability from beginning of the 5th year of utilisation and stays stable and high more than 10 years when using the proper cut regime. The chemical composition of the fresh material meets the requirements for livestock feed.

Galega plants got sometimes damaged due to severe (below -5°C) night frosts in spring or the first half of summer (beginning of June). Therefore the harvest of the first yield is postponed. Night frosts are usually not dangerous to the whole plant cover.

The need for carrying out ***the second trial*** arose already in the course of the above-described first study. It turned out (Laidna, 1987) that the problems of establishment and utilisation of the galega field needed specifying: whether to sow fodder galega in a pure stand or in mixture with grasses and which are the optimum times for cuts.

The object of the field trial established in May, 1986 was to study which tall grasses would be the most suitable for growing together with fodder galega and how the time of the first and second cut affect the yield and persistence of fodder galega.

The trial was established on sod-podzolic soil which humus content of 0...20 cm soil layer was 2.3...2.7% and pH_{KCl} was 5.9. The preceding crop was potato which had received manure (45 t ha^{-1}).

On the whole trial area fodder galega with sowing rate of 30 kg ha^{-1} was sown. Different grasses were sown crosswise with fodder galega rows (50% of pure sowing rate of a corresponding species): timothy – 5, cocksfoot – 10, tall fescue – 17, smooth bromegrass – 19 and reed canary grass – 8 kg ha^{-1}. The fertiliser background was

N0P35K66 kg ha^{-1} per year. The trial area was limed also with oil-shale ash in 1989 with the rate of 5 t ha^{-1}.

The yield was harvested twice during summer whereas there were two times of the first cut: early (plants` budding stage) – mostly on June 10…15 and late (beginning of flowering) – mostly on June 25…30. There were 8 second cut times (interval 1 week), in case of the early first cut mostly on August 15, August 29, September 11 and September 25 and in case of the late first cut mostly on August 22, September 5, September 18 and October 2.

The trial results showed that for getting herbage with a good yielding ability fodder galega has to be sown at least at the end of May. Careful soil cultivation and weed control are necessary. The percentage of fodder galega fluctuated in rather big limits (Table 7), in the last six years of utilisation (1994…1999) as the average of mixtures it increased considerably in case of early and late cut compared to the previous 7-year period. At the same time the percentage of fodder galega in the mixture depended only a little on the companion grass species and time of the first cut (Figures 3 & 4).

On the basis of content and yield of dry matter and crude protein (Table 7 & 8) it is difficult to prefer pure stands of fodder galega to mixtures or one mixture to another. In case of early first cut galega mixture with tall fescue and bromegrass had a little bit higher yield. With years the level of dry matter decreased a little (more in case of late first cut): as the average of the last 6 years compared to the previous 7-year period, 14…22% in pure stand of fodder galega and 16…25% in mixtures. In case of late first cut both pure stand and mixtures had somewhat higher yields of dry matter (accordingly 15 and 6%) but they were poorer in protein content.

Analogically with dry matter yield the tendency of decrease with years occurred on protein yield (24…25% in pure stand of fodder galega and 17…25% as the mean of mixtures). As the total of the whole trial period in case of late first cut, the mean of mixtures was almost by 9% less of protein than in case of early first cut (table 9), which difference was as the average of years, statistically significant. On the other hand, the protein yield of fodder galega`s pure stand was a little (8%) higher in case of late first cut. It was due to the fact that the decrease in protein content of fresh material in case of late first cut (plants were in a later development stage), was compensated by relatively bigger increase of dry matter yield in later cut.

The yield level of both pure and mixed stands of fodder galega varied by different years in rather big limits. The biggest differences occurred between very droughty (1992, 1999) and rainy (especially 1998) years. The herbages compared in the trial (6 in all) gave, as the mean of two cutting times in 1992, 1998 and 1999 dry matter on the average accordingly 6.07, 9.01 and 3.29 t ha^{-1} and 797, 1548 and 401 kg $ha^{-1}$of crude protein. The mean content of crude protein in dry matter was in the same years accordingly 13.1, 17.2 and 12.2%. So in very droughty years, in additon to the yield, its quality also decreased, most of all protein content in the dry matter of herbage.

Table 7. *Dry matter (DM) production from pure fodder galega stands and galega-grass mixtures in 1987...1999*

Companion grass	Share of galega in yield, %				Dry matter yield on the average per year					
	1987...1993		1994...1999		1987...1993		1994...1999		1987...1999	
	variation	mean	variation	mean	t ha^{-1}	%	t ha^{-1}	%	t ha^{-1}	%
				Early 1st cut						
1. None	35...77	63	52...78	68	7,87	100	6,76	100	7,36	100
2. Timothy	37...79	64	47...74	68	8,29	105	6,88	102	7,64	104
3. Cocksfoot	44...80	66	44...75	66	8,01	102	6,83	101	7,47	101
4. Tall fescue	50...82	64	59...77	69	9,17	116	7,18	106	8,25	112
5. Bromegrass	55...88	71	56...79	68	8,80	112	7,40	109	8,15	111
6. Reed canary grass	54...85	71	61...82	75	8,50	108	7,48	111	8,03	109
7. Mixtures mean	35...88	67	44...82	69	8,55	109	7,15	106	7,91	107
				Late 1st cut						
1. None	66...94	82	60...92	79	9,45	100	7,40	100	8,50	100
2. Timothy	50...84	71	49...83	75	10,00	106	6,79	92	8,52	100
3. Cocksfoot	49...82	65	36...79	71	9,05	96	6,83	92	8,03	94
4. Tall fescue	46...76	64	30...77	68	9,55	101	6,68	90	8,23	97
5. Bromegrass	48...82	67	26...65	59	9,43	100	7,58	102	8,58	101
6. Reed canary grass	48...84	68	29...78	69	9,30	98	7,59	102	8,52	100
7. Mixtures mean	46...84	67	26...83	68	9,47	100	7,09	96	8,38	98

Table 8*. Crude protein (CP) content and production from pure fodder galega stands and galega-grass mixtures in 1987...1999*

Companion grass	Content of CP in DM, %				Crude protein yield on the average per year					
	Mean		1987...1999		1987...1993		1994...1999		1987...1999	
	1987...1993	1994...1999	variation	mean	kg ha^{-1}	%	kg ha^{-1}	%	kg ha^{-1}	%
			Early 1st cut							
1. None	18,6	16,1	15,6...19,8	17,6	1464	100	1090	100	1292	100
2. Timothy	17,6	17,1	13,7...19,6	17,4	1460	98	1174	108	1328	103
3. Cocksfoot	16,7	16,7	14,3...19,6	16,8	1336	91	1143	105	1256	97
4. Tall fescue	16,8	17,0	13,7...19,0	16,9	1544	105	1221	112	1395	108
5. Bromegrass	17,7	17,4	14,2...19,2	17,6	1558	106	1285	118	1432	111
6. Reed canary grass	17,8	17,3	14,2...19,6	17,6	1516	104	1295	119	1415	110
7. Mixtures mean	17,3	17,1	13,7...19,6	17,2	1483	101	1224	112	1365	106
			Late 1st cut							
1. None	16,6	16,2	11,1...18,1	16,4	1570	100	1197	100	1398	100
2. Timothy	14,9	15,4	10,1...17,3	15,1	1488	95	1045	87	1284	92
3. Cocksfoot	14,2	15,0	10,1...16,5	14,5	1287	82	1025	86	1166	83
4. Tall fescue	14,8	15,1	8,8...16,7	14,9	1414	90	1011	84	1228	88
5. Bromegrass	14,6	13,8	8,6...16,6	14,4	1387	88	1050	88	1232	88
6. Reed canary grass	15,4	14,8	9,2...17,3	15,2	1434	91	1127	94	1292	92
7. Mixtures mean	14,8	14,8	8,6...17,3	14,8	1402	89	1052	88	1240	87

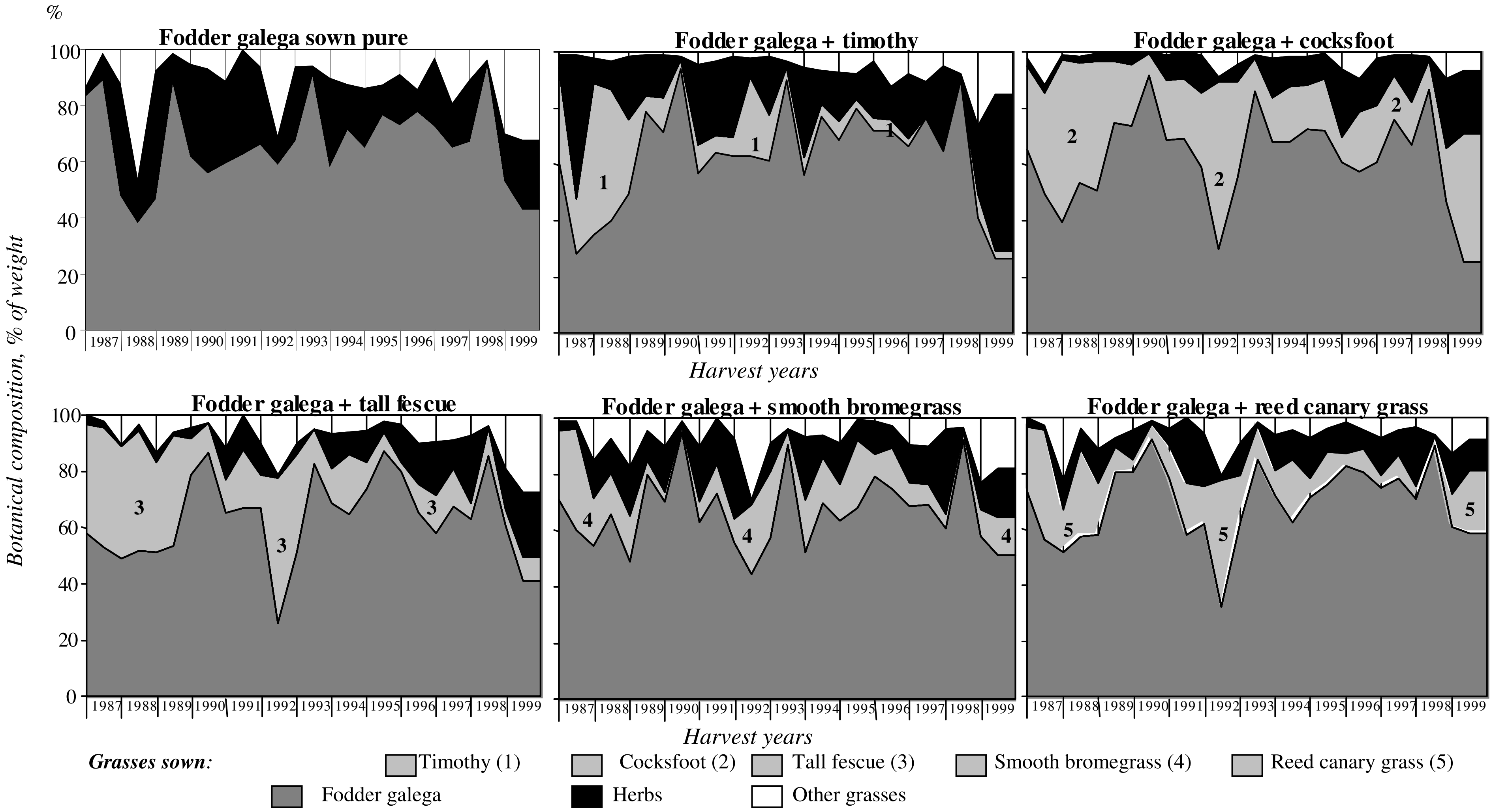

Figure 3. *Botanical composition of pure stands of fodder galega and its mixtures with tall grasses in 1987...1999 (early 1st cut)*

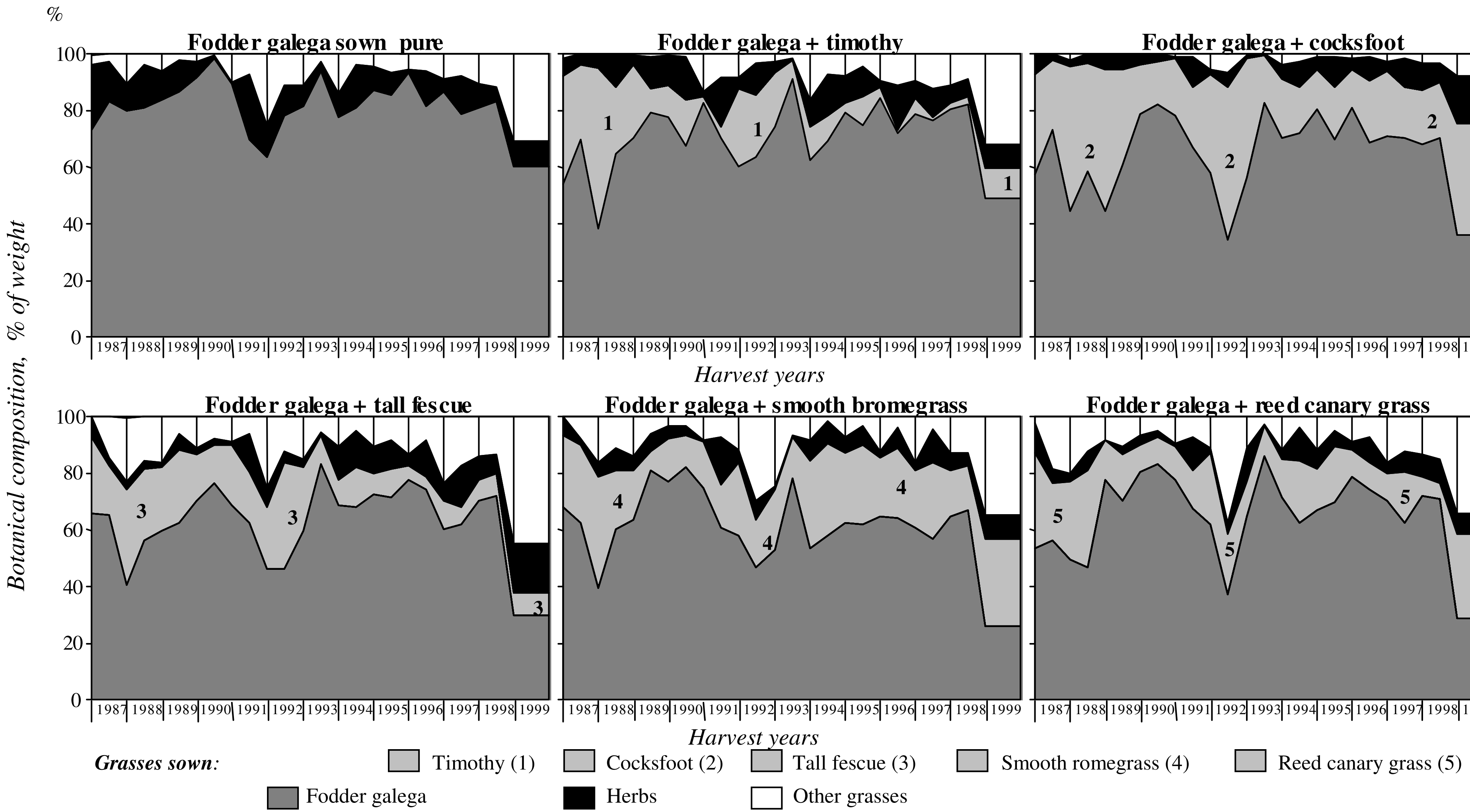

Figure 4. *Botanical composition of pure stands of fodder galega and its mixtures with tall grasses in 1987...1999 (late 1st cut)*

Table 9. *Influence of the time of the 1st cut on the annual yield of pure galega stand and galega-grass mixtures*

Companion grass	Increase/decrease (±) in the annual yield by the late 1st cut			
	Dry matter 1987...1999 mean		Crude protein 1987...1999 mean	
	t ha $^{-1}$	%	kg ha $^{-1}$	%
1. None	1.14	15.5	106	8.2
2. Timothy	0.88	11.5	-44	-3.3
3. Cocksfoot	0.56	7.5	-90	-7.2
4. Tall fescue	-0.02	-0.2	-167	-12.0
5. Bromegrass	0.43	5.3	-200	-13.9
6. Reed canary grass	0.49	6.1	-123	-8.7
Mixtures mean	0.47	5.9	-125	-9.2

Summing up the trial results with galega-grass mixtures on sod-podzolic soil, we can say that although in the trial organised in 1987…1999 both pure stands of fodder galega and its mixtures with different tall grasses gave the yield of almost the same amount, galega-grass mixtures (first of all with bromegrass, reed canary grass and tall fescue) should be preferred because the stems of fodder galega are then thinner and their edibility is better.

In Estonian conditions fodder galega is one of the most persistent leguminous fodder crops. Its pure stands and mixtures with tall grasses gave in South-Estonia on sod-podzolic soil yet in the 11th and 12th years of utilisation (1997 & 1998) 6.5...8.5 t ha^{-1} of dry matter and 1100...1300 kg ha^{-1} of crude protein per hectare.

Due to good persistence fodder galega is especially suitable for growing both in pure stands and in mixtures on such areas, which phased out of production and have been left without any cultivation for a long time: the soil becomes enriched with organic matter and nitrogen and due to dense plant cover the spread of weeds is depressed. Accordingly, it should be studied also whether fodder galega could become a troublesome foreign plant species which will endanger the balance of the present Estonian natural flora because here it is to deal with an aggressive, very persistent, perennial and vegetatively multiplying plant.

7. UTILISATION

7.1. Green fodder, hay and fodder concentrates

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Galega is mostly used for making silage and as a green fodder. But it is also a valuable material for making hay and fodder concentrates.

When using galega as **green fodder** it is most important to choose the right cutting time. Depending on the purpose of using the herbage, the right development stage should be chosen for cutting. The herbage which is cut in the earlier development stages contains more protein; with later cuttings we receive green fodder rich in dry matter and crude fibre, with less feed value and digestibility.

Fresh material of fodder galega, cut in the stage of shooting or budding is of high feed value. Although grazing is of great importance in feeding bovines and sheep in summer, the necessity for green fodder remains in case of keeping bovines in sheds, also in case of pigs, especially in the period before sows` farrowing. The most economic feeding method is feeding with green fresh material of galega, made fine already in the field.

Galega`s green fodder is especially significant in spring, at the end of May when other leguminous crops do not give the significant herbage yield yet, and also in late autumn when there is a shortage of green fresh material.

In a droughty years when the growth of pasture swards is poor, a plenty of additional fresh feed is needed. This problem can be solved by fodder galega which is a relatively drought-resistant fodder crop.

Compared to hybrid lucerne, the great advantage of fodder galega in making **hay** is that galega leaves, as the most valuable part do not fall at drying and harvesting.

For getting qualitative hay with good digestibility, it should be started with cutting in the beginning of flowering, at the latest. Hay can also be made from galega-grass mixtures where galega stems are thinner than in pure sowings and thus also with better edibility.

Fodder concentrates, primarily **leaf protein concentrate** have been made from galega`s valuable fresh material. This is enabled by green mass which is cut at the time of shooting or budding, with very high crude protein and carotene content.

At industrial production of leaf protein concentrate, the green juice from plant cells is pressed out, it is cleaned from additives (e.g. fibres) and later on thermally processed. By this, proteins will coagulate. The received protein concentrate can be dried and granulated or preserved as paste.

As for feed value and content of some essential amino acids, leaf protein granules from fodder galega are of high quality and they have been used in fodder diets for young cattle and nonruminants. They can also replace there the feed additives of animal origin.

Together with green cell juice, only a part of proteins is pressed out from green mass. Dried herbage granules can be made from the remained pressed mass and they are also suitable for feeding.

7.2. Ensiling of fodder galega

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Galega belongs to the group of legumes crop. Legumes are known to be difficult to ensile because they are highly buffering, have low water soluble carbohydrates (WSC) concentration, and often a low dry matter (DM) concentration. This may lead to a butyrate-type silage fermentation and great losses. Compared to other legumes such as red clover or lucerne, galega has even lower WSC and higher crude protein (CP) concentrations, and therefore the ensiling is more problematical. However, there are possibilities to reduce risky factors and improve fermentation. Herbage wilting usually improves fermentation conditions in the silage. The use of suitable additives may considerably reduce clostridial fermentation and losses. it is also possible to use galega-grass mixtures. Then the overall fermentation properties of silage material will hopefully be improved.

In order to study the ensiling of galega, two trials were carried out within the years 1997-1998 at the Estonian Research Institute of Agriculture (ERIA). One round big bale silage trial was carried out at Kelko farm. The silage material was galega or galega-grass mixture (50% of galega and 50% of grass) and the material was ensiled in 3-

litre glass jars. The jars were closed with a rubber lid. In 1997, the silages were made without any additive. In the second year the chemical additive Niben 5 l t^{-1} fresh matter (FM) and biological additive Silomeister-3 5 l t^{-1} FM were used. The treatments of big bale silage were made as follows: untreated control, Niben 5 l t^{-1} FM (4 and 6 layers of plastic film). The samples of big bale silage were taken after 4 months of ensiling and samples of pilot silage after 3 months. The chemical and microbiological analyses were made at ERIA laboratories. Aerobic stability of silage was determined under controlled aerobic conditions visually. The first mould colony detected on the silage surface was taken as a base of stability determination.

Table 1. *The chemical and microbiological composition of ensiling material (first cut, 12.06.97)*

Parameter	Galega	Galega + timothy	Galega+ meadow fescue	Galega+ cocks-foot	Galega+ ryegrass
Dry matter (DM), g kg^{-1}	193	248	236	210	209
Crude protein, g kg^{-1} DM	233	188	171	175	172
Crude fibre, g kg^{-1} DM	253	245	261	270	245
Crude ash, g kg^{-1} DM	109	87	86	87	86
Sugars, g kg^{-1} DM	62	70	120	85	118
Microorganisms, $\times 10^3$ g^{-1}:					
spores of aerobic bacteria	24.5	2.4	1.4	0.7	1.3
clostridium spores	0.45	0.045	0.045	0.015	0.009
lactic acid bacteria	0.1	0.13	0.6	0.03	0.3
yeasts	0.4	0.3	1.3	2.4	0.2
moulds	0.1	9.6	19.6	5.3	7.3

The chemical composition of herbage and fermentation products of pilot silage are presented in Tables 1-4. The results of big bale silage are presented in Table 5. In the first year when additives were not used, the silage quality of all treatments was very poor (Table 2). This was judged by high concentrations of butyric acid and butanediole and high number of clostridium spores. The pH value of silage was also too high, indicating poor fermentation. The use of different galega-grass mixtures did not improve fermentation. Even opposite effects appeared in mixture treatments, particularly when meadow fescue and cocksfoot were used. The both grasses resulted in the highest ammonia and butanediole concentrations and the highest losses. Despite the fact that the use of ryegrass reduced butyric acid in the silage twice, the silage quality still remained unsatisfactory.

Table 2. *The quality of silage made of galega or galega-grass mixtures and ensiled in 3-litre glass jars. The additives were not used and ensiling period lasted for 3 months*

Parameter	Galega	Galega + timothy	Galega + meadow fescue	Galega + cocks-foot	Galega + ryegrass
Dry matter (DM), g kg^{-1}	270	281	248	251	264
pH	4.9	5.0	5.0	5.0	5.2
Acidity	70	62	65	69	47
Sugars, g kg^{-1} DM	83	125	72	83	184
Amn.-N/ total N, %	5.6	5.0	10.2	7.1	6.5
Acetic acid, g kg^{-1} DM	8.5	7.5	5.6	6.0	11.4
Propionic acid, g kg^{-1} DM	1.5	0.7	2.4	2.4	0.8
Butyric acid, g kg^{-1} DM	23.3	21.0	19.4	23.5	12.5
Isobutyric, g kg^{-1} DM	0.4	0.3	0.4	0.3	0.3
Valeric acid, g kg^{-1} DM	0	0	0	1.2	0
Ethanol, g kg^{-1} DM	17.0	27.4	31.0	23.5	28.8
2.3-butanediole,g kg^{-1} DM	8.5	8.5	17.3	19.1	11.4
Microorganisms $\times 10^3$ g^{-1}:					
yeasts	2.13	4.4	3.8	6.30	4.99
moulds	2.06	<0.03	<0.03	0.03	<0.03
clostridium spores	11.0	14.0	14.0	14.0	4.5
Aerobic stability, days	>7	>7	>7	>7	>7
DM losses, %	9.4	7.9	16.2	13.5	14.8

In the second year the same mixture treatments were used. The pure galega was ensiled without any additive and with using Niben. The mixtures were ensiled without any additive and with using biological additive Silomeister–3.

The silage quality was greatly dependent on the use of the additive. When additives were not used the silage quality of all treatments was very poor as in the first year (Table 4). The use of Niben resulted in silage of good quality. Niben reduced about 21 times butyric acid and 8 times ammonia content in the silage. The dry matter losses were reduced 8 times. Niben reduced also the number of clostridium spores which is an important result from hygienic quality point of view.

Silomeister–3 also improved silage quality and reduced losses. However, the quality of silage still remained poor in mixture treatments. These results showed that Niben is an effective additive. The biological additive was not effective enough when a crop with low sugar content as galega was used in the mixture. Grasses increased the concentration of sugars and reduced buffering capacity of ensiling material but ensilability did not improve sufficiently.

The big bale silages were well fermented (Table 5). There were no significant differences between treatments. The results were somewhat surprising as galega is known to be difficult to ensile. The chemical composition of herbage and fermentation conditions were probably optimal. Therefore fermentation was good.

Table 3. *The chemical and microbiological composition of ensiling material (first cut, 4.06.1998)*

Parameter	Galega	Galega + timothy	Galega + meadow fescue	Galega + cocks-foot	Galega + ryegrass
Dry matter (DM), g kg^{-1}	200	227	228	205	238
pH	5.9	5.7	5.7	5.9	5.8
Crude protein, g kg^{-1} DM	208	142	147	150	171
Crude fibre, g kg^{-1} DM	222	201	231	230	198
Crude ash, g kg^{-1} DM	82	76	78	84	82
Sugars, g kg^{-1} DM	50	134	141	132	202
Microorganisms, $\times 10^3$ g^{-1}:					
spores of aerobic bacteria	0.80	0.10	1.85	0.30	0.45
clostridium spores	<0.004	<0.004	<0.004	<0.004	<0.004
yeasts	58.0	65.7	19.0	39.0	102.7
moulds	14.3	16.3	35.0	18.3	18.3

Table 4. *The results of silage fermentation made from galega or galega-grass mixtures and ensiled in 3-litre glass jars. The additives used were Niben and Silomeister-3 (SM-3). Fermentation period lasted for 3 months.*

Parameter	$LSD_{0.05}$	Galega		Galega + timothy		Galega + meadow fescue		Galega + cocksfoot		Galega + ryegrass	
		Un-treated	Niben 5 l t^{-1}	Un-treated	SM-3 5 l t^{-1}	Un-treated	SM-3 5 l t^{-1}	Un-treated	SM-3 5 l t^{-1}	Un-treated	SM-3 5 l t^{-1}
Dry matter (DM), g kg^{-1}	31.5	168	170	210	220	210	210	190	200	200	200
pH	1.5	5,6	4,2	4.4	3.33	4.1	3.3	4.2	3.4	4.1	3,4
Acidity	42.3	36	80	71	257	96	252	95	273	104	283
Sugars, g kg^{-1} DM	38.8	15	29	71	68	45	32	35	41	153	115
Amn-N/ total N, %	4.2	48.0	6.0	13.6	4.0	10.2	1.7	9.2	2.9	9.5	3.7
Acetic acid, g kg^{-1} DM	6.2	41.5	12.8	12.1	12.4	11.1	13.2	10.5	12.6	15.3	25.7
Propionic acid, g kg^{-1} DM	4.9	23.4	2.7	1.2	1.2	1.2	1.4	1.1	1.3	1.8	3.1
Butyric acid, g kg^{-1} DM	4.7	44.4	2.1	32.2	4.4	37.1	8.4	44.0	6.2	37.2	20.7
Isobutyric acid,g kg^{-1} DM	2.8	5.2	0	0	0	0	0	0	0	0	0.3
Valeric acid, g kg^{-1} DM	5.5	6.4	0	0	0	0	0	0	0	0	0
Ethanol, g kg^{-1} DM	8.4	45.2	13.7	36.7	16.4	31.1	16.8	32.6	12.5	32.9	23.2
2,3-butanediole,gkg^{-1}DM	6.8	15.9	0.9	7.8	1.2	11.4	3.4	6.6	1.0	9.3	7.6
Microorganisms, $\times 10^3$ g^{-1}:											
yeasts		5.28	9.75	163	8.80	3.80	13.4	0.85	11.7	1217	0.28
moulds		0.40	0.80	3.40	1.10	0.48	0.95	0.33	4.50	28.8	4.13
clostridium spores		0.70	0.01	0.27	0.02	1.48	0.02	1.73	0.02	0.49	1.25
Aerobic stability, days		6	6	7	>7	>7	5	>7	>7	>7	5
DM losses, %	4.3	15.7	1.9	8.0	3.1	8.9	4.5	8.1	3.2	8.9	5.3

$LSD_{0.05}$ – Least significant difference at 5% probability level (n=2)

Table 5. *The effect of using the additive and number of layers of plastic film on the quality of silage made from galega or galega-grass mixtures*

Treatment	DM g kg^{-1}	Crude protein g kg^{-1}	Crude fibre g kg^{-1}	Crude ash g kg^{-1}	Sugars g kg^{-1}	pH	Acidity	Amn.N /total N, %	Nitrate g kg^{-1}	Acetic acid g kg^{-1}	Butyric acid g kg^{-1}	Etha-nol g kg^{-1}	Butane-diole g kg^{-1}
Untreated, 4 layers plastic	202	173	289	82	10	4,2	151	6,4	0,7	19	0,4	11	0
Niben 5 l t^{-1}, 4 layers plastic	205	162	260	86	7	4,2	150	9,7	0,9	21	0,4	9	0
Untreated, 6 layers plastic	210	161	270	84	3	4,2	158	8,2	0,8	22	0,5	11	0
Niben 5 l t^{-1}, 6 layers plastic	215	169	282	80	6	4,2	149	8,3	0,8	19	0,2	10	0
Mean	208	166	275	83	7	4,2	152	8,2	0,8	20	0,4	10	0
$LSD_{0,05}$	15,7	12,2	21,4	7,4	7,8	0,5	15,5	4,1	1,2	4,8	0,8	3,4	0

$LSD_{0,05}$ – least significant difference at 5% probability level (n=3)

The results of pilot silage and big bale silage were contradictory. The results of pilot silages showed very poor fermentation or low silage quality when pure galega or mixtures were ensiled and no additives were used. Both additives improved fermentation considerably but Niben was more effective. Niben resulted in silage of good quality. The use of galega-grass mixtures did not improve fermentation.

The results of big bale showed good fermentation probably due to optimal fermentation condition in the silage. The research work should be continued.

7.3. Grazing

Grazing trials with fodder galega carried out at the Estonian Research Institute of Agriculture

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Galega is a herbage plant with early and fast growth, being used as green fodder or making silage. There has been quite a lot of experience in using galega for grazing, although plant's biological peculiarities don't correspond to it. Up till now there are a few research results on grazing with galega.

Very important for pasture is that when grazing there cattle, it should be constantly supplied with fresh grass of high nutritive value. Herbage plants are cut repeatedly at grazing (4…6 times during vegetation period). Due to frequent cutting plants can't grow high and therefore such herbage plants must have fast and good regrowth.

Traditional pasture swards are characterised by multitude of species and their great density. For getting large assimilating area, plants with different biological characteristics grow together, the majority of them are low grasses with basilar leaves and underground stolons. Legumes and grasses together in mixture ensure the high production and nutritive value of pasture sward.

A trial with pasture swards of different species composition was carried out at the farm of the Estonian Research Institute of Agriculture in 1998…1999. There were typical pasture swards (rich in white clover and lucerne, *M. sativa*) and galega.

The trial area was located on sod-calcareous soil on limestone, which humus content was 4.3% and pH 6.6. The content of P was 8 mg and K – 24 mg per 100 g soil. No nitrogen fertilisers were used.

Weather conditions were different in trial years. The year of 1998 was favourable for the growth of herbage plants. Their active vegetation started on April 20, in May they developed fast and shooted well. The whole summer was rainy and regrowth of plants on the pastures was quite good. In 1999 the vegetation period started a week earlier. May was quite cold and dry. Night frosts occurred for 19 times in May, it damaged herbage plants (including galega). Plants started to grow faster at the end of May. June and July were warm and dry. In the middle of July the pastures were brown and regrowth was stopped. It started to rain only in the III decade of September (precipitation in summer 53% of the standard)

The number of stocking rounds on typical pasture swards was five in 1998 and three in 1999. Considering the biological peculiarities of galega, such frequent grazing was not used – four grazings in 1998 and three in 1999. The dairy cattle (40 cows) of the experimental farm was grazed in the trial area.

The productivity of fresh material was determined before grazing by cutting method. Samples for botanical and chemical analyses were taken per a variant during each grazing. The digestibility of organic matter was determined by using the *in sacco* method. The content of metabolisable energy (ME) was calculated according to the data.

In spite of early development of galega in spring it could be started with grazing quite late. In 1998 it was first grazed on May 29 and in 1999 on May 30, which was a week later compared to typical pasture swards. The lateness was caused by severe night frosts in May. The regrowth period was 30 days for the second grazing round. It takes pasture swards mostly 15…20 days for that. The galega herbage has good edibility in spite of quite long regrowth period.

In the first trial year (1998) the increase of dry matter in galega's herbage per day in the first half of summer was 89...116 kg ha^{-1} and in the second half of summer 44...62 kg ha^{-1}. In the second year the increase of dry matter was accordingly 66...72 kg ha^{-1} and 13 kg ha^{-1}. The weather of the second year of the trial (1999) was in the second half of summer very dry.

Galega pasture was not grazed in August and in the first half of September for enabling plants to gather nutritive reserves needed for good overwintering. Nevertheless to that in spring of the second year the plant cover remained thin due to the influence of the previous year grazing. According to the data of botanical weight analysis in 1999 the yield of the first grazing contained galega only 39.3%, grasses 25.9% and several herbs 34.8%. Typical pasture swards contained herbs only 7...16% (Figure 1).

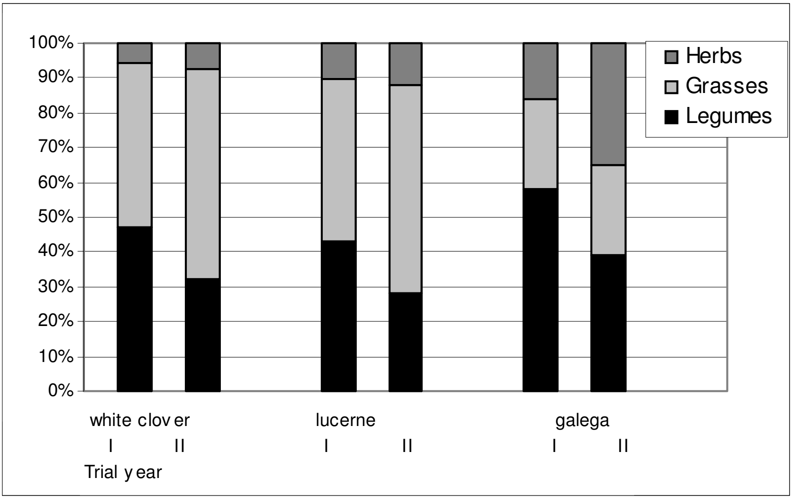

Figure 1. *Botanical composition of the different pasture swards*

Due to drought the share of legumes decreased in all swards, whereas in typical pasture swards mostly grasses replaced them. The herbs began to spread after the decrease of the galega's share in the sward, but the share of grasses remained on the same level.

Chemical composition of herbage was good at galega pasture (Table 1). The thinned sward and droughty summer decreased the productivity. In the second year of the trial only 4.3 t ha^{-1} of dry matter were received from galega at grazing and galega`s share in it was only 40%. But as the average of the two trial years, galega's sward productivity overcame the other swards (Table 2).

Table 1. *Chemical composition of herbage from galega pasture at grazing*

Stocking round	In dry matter, g kg^{-1}						
	Crude prot.	Crude fibre	Crude ash	P	K	Ca	Mg
1998							
First	250	226	116	5.0	43.3	10.1	2.0
Second	260	227	110	4.0	35.5	13.5	2.2
Third	245	228	103	3.9	37.0	11.5	2.1
Forth	236	223	117	4.2	34.4	16.8	2.1
1999							
First	170	193	90	3.7	35.8	7.4	1.9
Second	156	243	87	2.6	23.1	16.2	1.8
Third	150	220	91	2.7	26.7	10.2	1.9

Table 2. *The pastures yield and its nutritive value (average of 1998…1999)*

Swards	Yield, t ha^{-1}		Nutritive value of dry matter		
	Dry matter	Crude protein	Crude prot.%	Digesti-bility, %	ME MJ kg^{-1}
Rich in white clover	5.6	1.0	17.8	69	10.5
Rich in lucerne	5.8	1.0	17.2	71	10.6
Rich in galega	7.5	1.7	22.5	67	10.2

At all stocking rounds the content of crude protein in the herbage was high and in spite of a long growth period, the content of crude fibre was quite low. The lower protein content during the second trial year was caused by thinning of galega sward.

Nutritive value of the herbage of galega pasture at grazing was good. In the first year of the trial the pasture herbage contained 9.7…9.9

MJ $kg^{-1}$of metabolisable energy per dry matter. In the second year of the trial the nutritive value of the herbage was higher. During the first stocking round the herbage contained 11.7 MJ kg^{-1}, during the second 9.6 MJ kg^{-1} and during the third 10.4 MJ kg^{-1} metabolisable energy per dry matter.

Grazing trials with fodder galega carried out in Estonian Agricultural University

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In addition to leguminous species (clovers and yellow lucerne) traditionally grown in pastures, we have tried to establish grasslands with new species and varieties of legumes. In Estonia such legumes should be considered birdsfoot trefoil, hybrid lucerne Karlu and galega Gale.

Galega has proved to be capable to give great yields of green mass and dry matter in cutting system. In several cases galega has remained in the herbage even if it has been grazed from time to time due to shortage of green fodder.

In May of1995 the Department of Grassland Science and Botany of the Estonian Agricultural University established on sod-podzolic soil (Podzoluvisol) a pasture trial with mixtures of different legumes and grasses. A similar seed mixture of grasses was sown on a trial area, including 5 kg ha^{-1} of timothy Tika, 10 kg ha^{-1} of rye grass Raidi and 3 kg ha^{-1} of smooth-stalked meadow grass Esto. For obtaining numerous trial variants with different legumes (all in 4 replications), legumes were sown in addition to grasses (1 species or variety on each trial variant): either 4 kg ha^{-1} of white clover, 8 kg ha^{-1} of red clover, 4 kg ha^{-1} of alsike clover, 6 kg ha^{-1} of birdsfoot trefoil, 10 kg ha^{-1} of hybrid lucerne or 16 kg ha^{-1} of galega. For studying the cumulative effect of clover`s different species, 2 kg ha^{-1} of white clover, 4 kg ha^{-1} of red clover and 3 kg ha^{-1} of alsike clover were sown also in addition to grasses. The size of the established trial area was 0.4 ha. In the first two years 54 Estonian black-and-white cattle were grazed in this area (stocking rate 135 cows per ha^{-1}) and since 1998 there were 70 cows, thus 175 cows per ha^{-1}.

The area of the trial plot was 20 m^2, of which 5 m^2 was meant for determining the yield before grazing and the remaining 15 m^2 was grazed after that. After grazing the aftercut was made and the received afteryield was weighed in order to determine the edibility of grass (usage rate) and forage intake (the amount of eaten dry matter per one cow).

The effect of grazing (trampling, uneven cutting, animal excreta) on botanical composition and yield of the herbage sward was studied in the trial. As the result of trampling, the soil becomes thicker, the air regime of galega roots becomes worse and the emerging of a new stolons in the soil is inhibited. It can be expected that the effect of trampling on galega`s growth is dangerous. But excreta are very significant in pasture sward formation. A lot of nutrients losses are returned to the pasture by them and they also improve the biological condition of soil. Although excreta fall unevenly they favour the development and growth of galega. Uneven defoliation has usually unfavourable effect on legume crops because cattle prefer them to grasses. Such frequent defoliation inhibits also the persistence of galega in the pasture essentially. But at the same time if the species is not suitable for frequent grazing we can expect that it will remain in the herbage at variable utilisation (alternating cutting and grazing).

The trial results showed that galega developed slowly in the year of sowing. Therefore, when establishing the pasture, it has to be followed that other species which develop fast in the sowing year would not damage the development of galega. The sowing should be made early in spring so that galega could develop enough by autumn and prepare to overwintering. Due to long growth period (early sowing) the herbage can be used at least twice during the sowing year. In our trial we grazed twice and made one aftercut for controlling the field weeds which had not been eaten.

In the first year of utilisation the share of galega in the grass sward was 26% (Table 1). The regrowth of galega was quite fast, so it would be suitable for using as a pasture. But as the result of too frequent cutting, the supply of nutrients decreases in its underground stolons. Systematic frequent use reduces the persistence of galega in the herbage. Its share in the sward dropped quite evenly down to 13% by the end of the third year of utilisation. In a droughty summer of 1999 (the 4th year of utilisation) the percentage of galega in the pasture sward was only 4.6%.

Accordingly, the existent galega variety Gale is not persistent in pasture sward when grazing is started already from the first year of utilisation.

Table 1. *Persistence of legumes in mixtures at grazing and variable utilisation in 1996...1999*

Sward		1996	1997	1998	1999
Precipitation		245	329	495	172
May...September, mm		Percentage in yield, % of weight			
		Grazing			
White clover:	Jõgeva 4	62.5	24.5	32.8	38.3
	Tooma	64.5	24.5	35.8	36.5
	Sonja	63.1	22.7	32.7	20.4
Red clover: Jõgeva 433		69.1	38.7	41.2	10.4
Ilte		61.3	60.3	61.1	62.7
Alsike clover Jõgeva 2		55.3	12.3	0.7	7.4
Birdsfoot trefoil Norcen		53.4	31.6	28.8	10.0
Hybrid lucerne Karlu		65.7	61.5	52.5	59.2
Galega Gale		25.6	17.2	13.0	4.6
		Variable utilisation			
White clover Jõgeva 4		59.8	15.4	19.6	32.7
Birdsfoot trefoil Norcen		62.2	29.6	24.1	7.7
Hybrid lucerne Karlu		58.8	61.7	67.5	66.5
Galega Gale		16.0	23.8	25.4	9.5

The yielding ability of galega-grass mixture (Table 2) was similar to the birdsfoot trefoil-grass mixture. But the taste of fresh green material was better than of the above-mentioned species because the edibility of galega was better. The fresh material from white clover-grass pasture exceeded it by its edibility. The edibility of fresh material from galega-grass pasture was more or less equal to the edibility of fresh material from red clover-grass pasture. Since the yields from galega pasture were lower than from the pasture of red clover (especially compared to tetraploid red clover), the forage intake per area from galega grassland remained lower.

The persistence of galega in pasture sward can be improved by using it variably. In that case in the sowing year the first cut of pasture grass should be made somewhat later and it favours the persistence of galega. The very early cut in spring can be a reason why galega does not persist in herbage sward. Due to fast regrowth the galega sward can be grazed soon after the first cut.

Table 2. *Dry matter yield and edibility (on the basis of dry matter)*

Sward	Dry matter yield t ha^{-1}				Edibility %			
(legume variety)	1996	1997	1998	1999	1996	1997	1998	1999
				Grazing				
1. Jõgeva 4	4.85	4.94	5.67	2.74	72.8	67.6	71.1	81.4
2. Tooma	5.14	4.76	6.05	2.85	76.9	71.4	66.9	84.9
3. Sonja	4.78	5.19	6.33	2.37	78.1	71.7	66.2	83.1
4. Jõgeva 433	6.06	4.60	6.20	2.45	69.3	69.4	71.3	71.4
5. Ilte	5.46	5.90	7.15	3.37	72.0	73.6	73.4	82.5
6. Jõgeva 2	4.76	3.45	5.26	3.04	66.8	55.1	63.1	81.5
7. Norcen	4.62	4.81	6.22	2.91	62.5	72.4	67.0	79.0
8. Jõgeva 4, Jõgeva 433, Jõgeva 2	6.47	5.94	7,35	3.20	73.5	72.9	70.8	81.6
9. Karlu	5.63	7.65	8.35	4.55	65.0	76.6	71.3	72.7
10. Gale	4.40	4.06	4.53	2.90	72.0	73.9	65.3	80.3
11. Grasses N-0	3.64	4.66	5.05	2.61	54.8	78.3	61.8	74.7
12. Grasses N-150	5.60	5.15	7.24	4.64	64.5	69.5	52.9	81.0
				Variable utilisation				
13. Jõgeva 4	5.17	5.71	6.10	3.05	75.9	68.0	56.9	-
14. Norcen	5.50	5.75	7.69	3.56	80.3	73.8	60.9	-
15. Karlu	6.05	9.82	9.61	5.27	71.7	77.3	49.9	-
16. Gale	5.72	6.65	6.70	3.32	60.0	80.7	66.7	-
17. Grasses N-0	4.07	5.29	6.20	3.25	53.8	76.7	60.7	-
18. Grasses N-150	7.73	7.21	9.69	3.82	82.0	75.1	49.7	-

Galega can be used variably for 3 (seldom 4) times during summer. The more frequent variable utilisation should be followed by more extensive utilisation regime the next year. It would help to recover the herbage better.

The share of galega in the sward at its variable utilisation increased by years. Although it is known that galega tolerates drought quite well, the extraordinarily dry summer of 1999 had inhibitory effect on galega`s growth also at variable utilisation. Its percentage in the herbage fell from 25% down to 10%.

From the share of galega fallen down to 10% under extreme conditions we can assume that it will be restored in the following years. It is important that galega`s growth would not be restricted by some other factors (e.g. too frequent utilisation). Therefore we recommend after unfavourable year of growth to use galega's grasslands more extensively, so that galega plants could start blooming for once in the growth period. In that case plants can gather enough nutrients into their underground parts, which favours the emerge and growth of additional buds and lateral shoots.

Under conditions of variable utilisation the dry matter yields of galega-grass mixture were by years more or less equal to the yields of the sward with birdsfoot trefoil (6…7 t ha^{-1}). At the same time their yielding ability was lower than of hybrid lucerne Karlu (6…10 t ha^{-1}). The increase of galega`s share in the herbage guaranteed also the increase in dry matter yield. Therefore it is very important to ensure favourable conditions for galega`s persistence and spread.

For getting a better review of yielding ability of different swards we compare the average yields of 3 trial years (1996…1998), table 2. Here we do not include an extraordinarily droughty year of 1999 when the yields of all swards were similarly low. The grazed grasslands which were established for our trials can be divided into 5 groups by the level of dry matter yield. The highest yield was received from the sward of hybrid lucerne Karlu – 7.21 t ha^{-1}, it was followed by the mixture of clovers (Jõgeva 4, Jõgeva 433 and Jõgeva 2) – 6.59 t ha^{-1}, red clover Ilte – 6.17 t ha^{-1} and grasses on the background of N-150 – 6 t ha^{-1}. Relatively similar dry matter yields were received from the swards with white clover varieties Jõgeva 4, Tooma and Sonja, birdsfoot trefoil Norcen and red clover Jõgeva 433 – 5.15…5.62 t ha^{-1}. The fifth group, the group of swards with the lowest yield included galega Gale, alsike clover Jõgeva 2 and grasses on the background of N-0 - 4.33…4.49 t ha^{-1}.

At variable utilisation the yields from the same swards were, as the average 24% higher than at grazing (dry matter yields accordingly 6.7 and 5.39 t ha^{-1}) and aligned as follows (t ha^{-1}): Karlu - 8.49, grasses on the background of N-150 - 8.21, Gale – 6.36, Norcen – 6.31, Jõgeva 4 – 5.66 and grasses on the background of N-0 – 5.19.

The edibility of fresh material from galega-grass mixture was better than from birdsfoot trefoil-grass and hybrid lucerne-grass mixtures. The edibility of galega's herbage exceeded also the edibility of pure grasses sward. The data about the edibility of herbages of the year 1999 at variable utilisation are missing (see table 2) because only one considerable cut could be made (25.06.99.) and only on the 4th of October it made sense to cut for the 2nd time the trial area (dry matter yield of most variants was only 0.1...0.2 t ha^{-1}). It was not succeeded in grazing in the meantime since due to very severe drought the growth of all swards were very poor after the first cut.

The forage intake, which have an essential effect on milk production per one hectare of grassland depended also on the yielding ability of pasture sward. So the pasture of hybrid lucerne Karlu was surely more productive than galega`s pasture. But when comparing with the pastures of other legumes (white clover, birdsfoot trefoil) which were used variably, the galega's sward was more productive because the bigger amounts of forage intake can predict more milk.

Summing up, we can say that on the basis of our trial galega is not suitable for grazing from the first year of utilisation. Variable utilisation (alternating cutting and grazing) favours the persistence of galega. On the ground of practical experience we can recommend to use galega for cutting in the first years of growing and after formation of a strong herbage use it variably either for grazing and cutting or for not so frequent grazing.

8. FODDER GALEGA AS AN IMPROVER OF SOIL FERTILITY

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Galega growing is of one possibilities to improve soil fertility. As a leguminous fodder crop it has an enormous root system, which enriches soil with organic matter and biologically fixed nitrogen and improves structure.

Galega leaves more organic matter into soil as root residues and harvest waste than other perennial legumes known by us. It develops more and more young roots and stolons while the older ones decay, as the result of which the mass of root residues and the amount of nitrogen in soil will increase.

During one year about 7 tons of roots per hectare (calculated on dry matter) were left into limestone rendzina, but in two years more than 10 tons (Raig, 1980). In case of mixtures with fodder galega the root mass was the same as in case of pure stands of galega but the ratio of small and big roots had changed as well as their distribution in different soil horizones.

186...483 kg ha^{-1} of nitrogen, 15...41 kg ha^{-1} of phosphorus, 53...105 kg ha^{-1} of potassium and 33...100 kg ha^{-1} of calcium were left annually into soil in a soil layer of 30 cm by pure stand of galega (Table 1).

Table 1. *Root mass of galega and other perennial field grasses, its P, K, N and Ca content and effect on humus genesis in soil (Raig et al., 1994)*

Soil	Crop	Soil layer cm	Root mass t ha^{-1}	Hu %	In roots P %	In roots K %	In roots N %	In roots Ca %	N kg ha^{-1}
1	2	3	4	5	6	7	8	9	10
Pebble sod-calcareous soil	galega	0-30	13.5	4.7	0.16	0.54	1.83	0.74	247.0
	barley after galega	0-30	9.53	3.7	0.10	0.32	0.98	0.54	24.7
Gley soil	galega	0-30	11.8	13.6	0.13	0.45	1.67	0.78	197.0
	barley	0-30	1.4	8.4	0.11	0.27	0.98	0.50	13.7
Sod-calcareous soil on limestone	galega	0-10	8.9		0.21	0.75	1.40	0.36	124.6
		10-20	3.7	3.6	0.17	0.75	1.48	0.36	54.7
		20-30	0.7		0.20	0.71	1.82	0.39	12.3
	hybrid lucerne	0-10	8.4		0.14	0.58	1.88	0.43	157.9
		10-20	3.9	3.7	0.14	0.71	1.96	0.36	76.4
		20-30	2.3		0.16	0.62	1.90	0.32	43.7
	red clover	0-10	6.1		0.28	1.00	1.96	0.79	119.5
		10-20	0.9	2.9	0.27	0.79	1.96	0.57	17.6
		20-30	0.3		0.21	0.66	1.86	0.54	5.5
	timothy	0-10	4.8		0.13	0.50	0.92	0.25	44.1
		10-20	1.1	2.8	0.14	0.62	0.95	0.29	10.4
		20-30	0.25		0.15	0.33	1.15	0.50	2.3

1	2	3	4	5	6	7	8	9	10
Sod-	galega	0-10	15.2		0.19	0.50	2.30	0.36	349.6
podzolic		10-20	4,8	2,67	0,17	0,42	1,82	0,29	87,4
soil,		20-30	2.2		0.17	0.42	2.07	0.29	45.5
sandy silt	hybrid	0-10	7.8		0.16	0.75	1.51	0.54	117.7
loam	lucerne	10-20	3.9	2.66	0.13	0.87	1.40	0.29	54.6
		20-30	1.8		0.11	0.66	0.95	0.18	17.1
	red	0-10	3.2		0.26	1.25	1.62	0.54	51.8
	clover	10-20	1.2	2.49	0.23	0.71	1.82	0.36	21.8
		20-30	0.4		0.25	0.66	2.30	0.59	9.2
	timothy	0-10	3.7		0.17	0.33	1.29	0.29	47.7
		10-20	0.7	1.87	0.22	0.37	1.65	0.43	11.5
		20-30	0.4		0.18	0.33	1.46	0.54	5.8
Gley soil,	galega	0-10	10.4		0.19	0.71	1.57	0.29	163.3
clay loam		10-20	0.9	3.5	0.17	0.58	1.76	0.18	15.8
		20-30	0.4		0.16	0.58	1.72	0.32	6.8
	hybrid	0-10	5.3		0.21	0.95	1.60	0.43	84.8
	lucerne	10-20	3.3	3.4	0.20	0.91	1.15	0.25	37.9
		20-30	1.5		0.14	0.50	1.54	0.25	23.1
	red	0-10	5.2		0.20	0.91	1.40	0.50	72.8
	clover	10-20	1.0	2.7	0.17	0.46	1.26	0.46	12.6
		20-30	0.3		0.13	0.71	1.62	0.50	4.2
	timothy	0-10	8.7		0.19	0.75	0.71	0.18	61.7
		10-20	1.8	2.6	0.16	0.63	1.20	0.32	21.6
		20-30	0.6		0.18	0.58	1.18	0.43	11.6

On sod-calcareous soil in the layer of 0…25 cm there were 12.7 tons of air-dry roots of fodder galega and on drained gley soil 13.1 tons per ha. There were 22.8...24.2 kg of P in the roots of fodder galega, 93.1…96.4 kg of K and 178…182 kg of N (Viil, 1995).

The effect of galega growing on soil structure can most of all be explained by the fact that due to long persistence (ten and more years), structural aggregates of soil in galega field are not broken into pieces by cultivation. Accumulation of fresh N-rich organic matter in soil favours forming and strengthening of structural aggregates.

On sod-calcareous soil the accumulation of organic matter was observed in the upper layer of soil horizon (0…5 cm). The soil surface was constantly covered with lodged plant stalks which acted as mulch. Since soil was not cultivated, the accumulation of organic matter was favourable. Therefore the surface layer of soil neither dried so fast nor was a subject to the influence of rainfall which in turn were of great significance at forming soil structure. The studies of structural situation of soil at Kuusiku trial fields showed that after growing fodder galega for 10 years the macrostuctural (aggregates 0.25…5 mm) and microstructural (aggregates 0.01…0.25 mm) composition of soil was better than growing cereal as monocrop (Tables 2 and 3).

Since fodder galega improves soil fertility more than other perennial field crops, it is a good preceding crop both for cereals and potato.

Aftereffect of galega as a preceding crop was for the first time examined on sod-calcareous soil on limestone. The trial was established in 1980 with barley, spring wheat and oats in the field, where galega had been grown six years. In A-variant after the first cut of galega in the beginning of June the plant cover of galega was destroyed by a disk, after two weeks it was disked one more time and then the field was ploughed. Until autumn the field was kept clean by the help of surface cultivation methods in order to exhaust and damage galega stolons. In B-variant it was started with soil cultivation work after the second cut of galega in September. The field was disked and then ploughed. Trial results are shown in Table 4. Most of the extra yield of cereal as aftercrop was received where disking and ploughing was started after the first cut of galega in June. In that case all galega plants were also damaged. The disking and ploughing after the second cut in autumn were less effective from the point of view of damaging galega as a foreign crop and extra yields of post-crop were lower. Depending on the crop in variant A the extra yield was 0.9...1.4 t ha^{-1} and in variant B it was 0.4...0.9 t ha^{-1}.

Table 2. *Macro-aggregate composition of sod-calcareous soil (%) (Jõgi, 1993)*

Crop	Hu	N	Diameter of fraction, mm							
	%	%	>7	7...5	5...3	3...2	2...1	1...0,5	0,5...0,25	<0,25
0…5 cm layer of soil horizon										
Galega	4.7	0.20	13.6	10.3	16.4	15.8	26.0	2.7	6.4	8.9
Cereal	3.7	0.15	26.5	12.2	15.1	11.9	20.7	1.5	3.5	8.7
15...20 cm layer of soil horizon										
Galega	3.6	0.16	16.3	11.4	18.3	15.7	23.4	1.7	4.8	8.4
Cereal	3.6	0.15	25.3	12.3	14.5	13.1	20.1	1.7	3.9	9.3

Table 3. *Micro-aggregate composition of sod-calcareous soil (%) (Jõgi, 1993)*

Crop	Diameter of fraction, mm						
	1...0,5	0,5...0,25	0,25...0,05	0,05...0,01	0,01...0,005	0,005...0,001	<0,001
0...5 cm layer of soil horizon							
Galega	1.9	2.6	63.1	25.1	3.9	2.1	1.3
Cereal	1.6	2.1	56.3	29.6	5.9	3.4	1.1
15...20 cm layer of soil horizon							
Galega	1.7	2.5	62.7	24.5	4.1	2.7	1.7
Cereal	1.5	2.2	57.2	28.8	4.2	4.6	1.6

Table 4. *The aftereffect of galega growing on the yield of spring cereals (t ha^{-1}) depending on the time of soil cultivation (Raig, 1988)*

Cereal	Trial variant		
	A After the first cut	B After the second cut	Control Resowing of cereal
Oats	3.6	3.1	2.7
Spring wheat	3.5	3.3	2.5
Barley	4.3	3.8	2.9

The trials carrried out on sod-calcareous and drained gley soils showed that positive aftereffect of galega growing remained for 2…3 years (Table 5).

Table 5. *The effect of different preceding crops and N-fertilisation on the yield of summer barley (kg ha^{-1}; Viil, 1995)*

Year of after-effect	Preceding crop galega				Preceding crop barley			
	Yield	extra or under yield			Yield	extra or under yield		
	N0	N20	N40	N60	N0	N20	N40	N60
				Sod-calcareous soil				
1.	4580	30	-450	-1050	2620	840	1070	1770
2.	2550	220	170	110	970	1220	1420	2070
3.	2850	600	1210	1590	2490	930	1310	1500
				Drained gley soil				
1.	3560	-90	-1250	-1550	1790	240	800	950
2.	2260	80	70	-30	1940	360	760	710
3.	2070	700	680	1020	1410	1360	1120	1300

The trial with spring barley showed that galega as a preceding crop is able to supply totally the cereal with nitrogen in the first and second year, so giving extra nitrogen fertilisers, especially in the first year of aftereffect is useless.

Analogical results were received on sod-calcareous soil on limestone where the effect of organic matter left into the soil after growing galega for two years and the effect of nitrogen fertilisation on the yields of the spring barley Elo were investigated. From the trial results of the first year became obvious that the control variant on the N0 level gave even some extra yield compared with the trial variant with 60 kg of N per ha (Table 6). The yields of the second year of aftereffect were low due to poor precipitation in vegetation period, but on the ground of nitrogen left into soil by galega, the yield of the control variant was as high as of other variants. It can be expected that after growing galega the soil is so rich in nitrogen that it satisfies the need of cereals for this nutrient for the next two years. Giving extra N-fertilizer does not increase the yield.

Table 6. *The aftereffect of galega growing on the yield of the spring barley Elo in the next two years*

Trial variant, N kg ha^{-1}	Yield t ha^{-1}	
	1st year	2nd year (very poor in precipitation)
N0	6.2	2.6
N30	6.4	2.7
N60	5.8	2.6

Comparison of different soil cultivation methods (Table 7) showed that preparing galega field for growing the following crop and controlling the vitality of galega plants as a foreign crop, it was economically more effective to use combined technology – to spray with the herbicide Roundup (360 g l^{-1} glyphosate) 5…6 l ha^{-1}, which has generally damaging effect and after that in two-three weeks plough (22...25 cm) or use a cultivator (18…20 cm).

The resistance of galega plants to mechanical and chemical effects was quite weak. By the end of the first year of growing the following crop (spring barley) there were 188 galega plants on 10 m^2, but by the end of the second year only 52. They did not practically occur in the third year. All annual weeds (white goosefoot, field pennycress, field hedge mustard, hemp nettles, etc.) were controlled out by herbicides. The signs of outward damage occurred also on galega plants in a week or two after spraying. Galega plants turned light green with a yellowish colouring. Their vegetative growth stopped.

Table 7. *The consumption of working time and diesel fuel and the yield of spring barley in the case of different cultivation techniques used after galega growing on sod-calcareous soil (Viil, 1995)*

Cultivation variant	The consumption of		Yield of
	working time t ha^{-1}	diesel fuel l ha^{-1}	barley kg ha^{-1}
Autumn ploughing, using of knife-harrow, stubble cultivator and cultivator-harrow	6.36	63.5	3610
Autumn ploughing, spraying with Roundup, using of stubble cultivator	4.78	47.1	3160
Spraying with Roundup in autumn, using of stubble cultivator, spring ploughing	4.78	47.1	3720
Spraying with Roundup in autumn, using of stubble cultivator in autumn	1.92	22.3	4040
Spraying with Roundup in autumn, spring ploughing, using of stubble cultivator	4.78	47.1	4230
Spraying with Roundup in autumn, spring ploughing	3.12	28.3	4090
Spraying with Roundup in autumn, autumn ploughing	3.12	28.3	4150
Spraying with Roundup in autumn, using of stubble cultivator, autumn ploughing	4.78	47.1	3920

Therefore they were supressed into the lower layer. But by autumn, by the time of harvesting the galega plants had recovered and reached medium and upper layer of plant cover.

Galega plants were quite resistant to the glyphosate containing herbicide with total damaging effect. When cultivating the galega field mechanically, by the end of the first year of growing the following crop, there were 92…101 galega plants on 10 m^2, in the variant of using mechanical cultivation and herbicide together, where it was sprayed in early autumn two-three weeks before autumn ploughing with Roundup 5…6 l ha^{-1}, there were 81…95 galega plants per 10 m^2.

The duration of aftereffect of galega growing on winter cereals depended greatly on the method of field cultivation. When using mechanical methods of soil cultivation, winter rye should be pre-ferred to winter wheat when growing winter cereals (Table 8). The average yield of winter wheat has remained lower than the average yield of winter rye by 1900 kg per ha or by 11.4%. The sowing rate and fertilisation (N70) in spring had no significant effect on the yield of winter rye, but it did have the effect on winter wheat.

Table 8. *The dependence of the yield of winter cereals as the following crops of fodder galega on sowing rate and fertilisation (Viil, 1995)*

Sowing rate seeds/ m²	N kg ha^{-1}	Yield of winter rye kg ha^{-1}	N effect kg ha^{-1}	N effect %	Yield of winter wheat kg ha^{-1}	N effect kg ha^{-1}	N effect %
400	0	4560	-	-	2460	-	-
	70	4520	-40	-0.9	2460	0	0
500	0	4490	-	-	2640	-	-
	70	4570	80	1.6	2810	170	6.4
600	0	4740	-	-	2720	-	-
	70	4650	-90	-1.9	3030	310	11.4

Growing winter cereals after galega, contrary to spring cereals, influenced strongly also the growth of galega plants, together with common coach grass, being in association. After harvesting the first cut in the middle of June the galega field was ploughed in the middle of July. With the following repeated 8..12 cm deep cultivations (with a cultivator and harrow) the trial area was kept free of plants until sowing of winter cereals on the first decade of September. There were 5…7 galega plants on 10 m^2 when growing winter rye and 18…20 galega plants when growing winter wheat in the variant cultivated such way before the next year harvesting of winter cereals.

Realisation of potential effectiveness of galega growing depended on the intensity of soil cultivation. In the variant with usual technology (Roundup+ploughing+soil cultivation before sowing) 3500…4200 kg of seeds of winter rye per one hectare were obtained. In minimised cultivation (Roundup+surface cultivation) galega plants maintained their vitality. The plants of winter rye were supressed into the lower layer. Therefore their yield turned out to be also low, only 300…550 kg of seeds per one hectare.

The aftereffect of galega growing on winter wheat was studied in the galega field grown on sod-calcareous soil on limestone for seven years. The trial field was treated in June with the herbicide Glialka (360 g l^{-1} glyphosate) – 3 l ha^{-1} and after that the field was disked and ploughed. Nitrogen fertiliser was given in spring, three different application rates of N – 0 kg of N (control), 30 kg of N and 60 kg of N per ha were used. The results of the first year showed that the yields from the control variant were comparatively high and almost at the same level with the ones received from other fertiliser variants. With application rate of NO the yield was 4.05 t ha^{-1}, in case of N30 and N60 the yields were accordingly 4.62 and 5.45 t ha^{-1} (table 9). The content of crude protein in the all yields was rather high, 13.4...14.4%. The 1000-seed weight did not differ significantly between the trial variants.

Table 9. *The yield of winter wheat Holme and its quality in the aftereffect trial of galega growing*

Trial variant	Yield t ha^{-1}	Content of crude protein, %	A 1000-seed-weight, g
N0	4.05	13.4	37.6
N30	4.62	13.8	38.2
N60	4.45	14.4	38.2

Galega growing had positive aftereffect also on potato yields. In the first year, in case of potato Vigri, almost equal yields per hectare were received both from control variant (N0) and the variant where 80 kg of N was used per hectare (Figure 1). In the second year of aftereffect, the effectiveness of using mineral fertiliser appeared in case of potato Van Gogh. Obviously there were not enough nutrients in the control variant any more. Trial variants N40 and N80 gave extra yield of 8...10 tons.

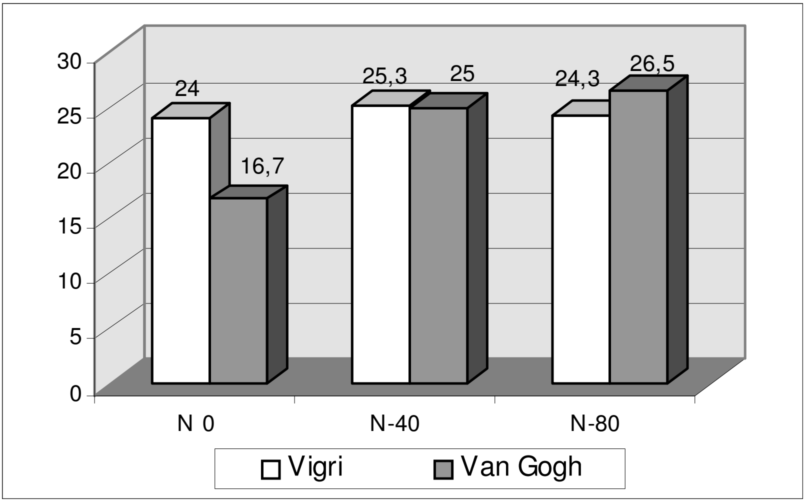

Figure 1. *The aftereffect of galega growing on potato yields (t ha^{-1}), in the first year on variety Vigri and in the second year on the variety Van Gogh (t ha^{-1})*

Since every year the root system of galega and overground parts leave a big amount of organic matter and nitrogen into soil, galega is in every respect very important for increasing soil fertility as a preceding crop in crop rotation.

The yield increasing effect of galega growing has been proved by above described investigations. It seems practical to establish galega fields in the areas with relatively low soil fertility or in the areas which have not received organic fertilisers and have left without any cultivation for a long period.

The resowing of galega on the same field have been unsuccessful. So the crop rotation in case of galega is necessary.

9. THE POSSIBILITIES OF USING FODDER GALEGA IN RECULTIVATING OIL-SHALE OPEN PITS

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Oil-shale is one of the main natural resources in Estonia. Both mining on and under the ground are used (mining in open pits and chambers). In late years mining in open pits is used more often.

Oil-shale mining causes significant damage to natural environment – the soil and water horizons are destroyed and water is polluted. The pre-condition for renewing and improving the environment is restoration of former productiveness of damaged areas and functions – recultivation of soil. In the course of technical recultivation of soil the mining area of the open pit is refilled with materials which were transported from the area and recovered with soil which was removed previously from the mined area.

Afforesting has shown good results in biological recultivation of such soils in Estonia. We still have less experience in recultivating into arable land.

The extension of agriculturally recultivated area of oil-shale pits became actual since the year 1974, after the open pit of Aidu started to work – the open pit covered over 700 ha of agriculturally used fertile lands of northeast Estonia (thickness of humus horizon mostly 25 cm, humus content 2.0%). After mining oil-shale, the areas of Aidu open pit had to be recultivated technically and restored into agriculturally used artificial soils.

When starting to use the open pit areas as an arable land, the main obstacle turns out to be their stonyness and low content of nutrients. In 1976 trials of agricultural recultivation were established at the open pit of Aidu in order to study the agricultural qualities of artificial soil. The stonyness of soils, the size of soil particles and the content of organic carbon and nutrients in soil were under investigation. Also the density of soil layer and its hydrofphysical properties were studied. The trials were established for investigating the yielding ability of spring barley, winter rye, potato and hybrid lucerne on the given soils. The results of these trials showed that the amount of yield depended on the technical level of carrying out recultivation, most of all on surface-levelling of the transported for refilling materials and on thickness and density of this layer and other factors (Kaar et al., 1991).

The research about the possibilities of biological recultivation of artificial soils in the open pit of Aidu with the new leguminous fodder crop galega was started in Estonia. The object was to find out whether there were advantages in growing galega compared to other field crops. Trials with galega on recultivated artificial soils were started in 1989. They were established in the areas which were filled with deposit materials, then surface-levelled and covered with 40…60 cm of soil layer. For comparison the swards with hybrid lucerne and with mixtures of galega and meadow fescue and also spring barley were included into trials.

The species were sown early in spring and P65K168 fertilization were used. The humus content of soil layer was 2.0…2.8%, pH 6.5…7.2, the content of K was 3.3…9.5 mg 100 g^{-1} and P 8.0…12.1 mg 100 g^{-1} air-dry soil. The soil texture was loam and density 1.3…1.8 g cm^{-3}. The content of heavy metals in soil was also determined. The soil contained Pb 1.3…1.47 mg 100 g^{-1} , Cd 0.02…0.03 mg 100 g^{-1}, Cr 0.2…0.3 mg 100 g^{-1}, Ni 0.3…0.5 mg 100 g^{-1} and Hg 0.006…0.009 mg 100 g^{-1} air-dry soil. Cu content was high – 4.0 mg 100 g^{-1}.

During the research the root mass of all crops being in the trial was determined in the soil layers of 0…15, 15…30 and 30…45. 20 deep diggings were used for this purpose. The roots were separated by washing them out with water and the chemical analyses of roots were made. Deep diggings for assessing the spread of root system were made to the limit which was practically also the limit of the spread of the root system (the main root of lucerne penetrated sometimes even deeper).

The research results about the amount of root mass of galega and other field crops, its P, K, N and Ca content and humus content of sod-calcareous technically generated soil on recultivated area of open-pit of Aidu are shown in Table 1.

The all soil horizons were closely twisted with galega`s root mass. The weight of air-dry root mass of galega in the layer of 0…45 cm reached in case of pure stands up to 20...22 t h^{-1}. Hybrid lucerne had also the strong and big root system. Barley's root system was three times smaller. Although the persistence of galega on technically generated soil was shorter (3-5 years) than usual, some increase of humus content in soil was observed at that time, most of all in the upper layer of soil horizon. It can be explained by constant renewing of galega's underground stolons, i.e. the older ones decay and the new ones emerge.

Table 1. *Root mass (air-dry) of galega and other field crops, its P, K, N and Ca content and humus content of technically generated soil on recultivated area (Raig et al., 1994)*

No of digging	Crop	Soil layer cm	Root mass t ha^{-1}	Hu %	In roots				N kg ha^{-1}
					P %	K %	N %	Ca %	
I	Galega	0-15	12.9	4.5					
		15-30	5.9	2.3	0.17	0.63	1.55	1.36	311.5
		30-45	1.3	2.0					
II	Galega	0-15	13.6	3.19					
		15-30	7.5	2.67	0.26	0.77	2.0	1.17	440.0
		30-45	0.9	2.59					
III	Galega+	0-15	10.2	2.58					
	meadow	15-30	4.2	2.56	0.30	0.20	1.8	1.1	281.0
	fescue	30-45	1.2	2.23					
IV	Barley	0-15	4.8	2.82					
	after	15-30	2.0	2.73	0.22	0.95	1.62	1.14	149.0
	galega	30-45	0.4	2.76					
V	Lucerne	0-15	11.6	2.2					
		15-30	5.6	2.17	0.22	0.77	1.91	0.97	360.1
		30-45	1.7	2.05					

Trial results about the possibility of galega growing on recultivated technically generated soils were good as it was expected. Galega grew well on the recultivated area of the open pit of Aidu, the dry matter yield in the third and fourth year of use was 8...11.1 t ha^{-1} and the content of heavy metals in overground parts was within the allowed limits. Here and there some trial areas with lower yield were found which was due to bad surface-levelling of used for filling materials. Less than optimum (40-60 cm) thickness of humus horizon was also found, especially at the ends of the field. It had the effect on water, air, and nutrition regime of the plant.

The results showed that the roots of leguminous field crops (galega, lucerne) left a lot of nitrogen into soil (312...440 kg ha^{-1}), enriching the technically generated soil with this nutrition. So the humus content of techically generated soil can essentially be increased by organic matter produced by leguminous field crops. Galega growing is one of the possibilities of increasing and preserving soil energy resources – humus and nitrogen. It should be considered when planning grass swards on recultivated areas. Galega growing guarantees consistency of living organisms in soil and humus formation, and on its root system' mineralisation nutritions are gradually released. Leguminous crops fix nitrogen but no P, K and Ca comes into soil additionally. This shortage has to be compensated by mineral P and K fertilisers.

When restoring production capacity of soil and increasing soil fertility, perennial leguminous fodder crops play a significant role in the biological system of plant – soil. Due to biological peculiarities, galega with a big root system and stolons favours more than the others the restoring of soil fertility, because it leaves more nitrogen and root mass into soil than the others. Due to the influence of root remains, the soil enriches with an essential characteristic of soil fertility – organic matter; the content of humus and nitrogen increases and soil structure improves.

The process of forming soil fertility is very long. In cultivation of recultivated areas under leguminous crops in livestock farming, some amount of plant`s phytomass will be returned to the fields as manure. But in case of growing cereals and potato, nutrients are constantly removed, and it should be balanced in the system of plant-soil by organic matter and nitrogen produced by perennial legumes.

Growing of galega on recultivated areas has several advantages. Soil enriches with organic matter of roots and stolons, humus genesis and accumulation of nitrogen are favoured and the soil structure will be improved. The loss of N, P, K and Ca from soil decreases as they are bound biologically. It is possible to limit the number of soil tillings since the fields are with relatively long persistence (at least five years). In galega cultivation it can be saved economically due to the fact that no additional mineral nitrogen fertilizer is needed and no expenses are made on getting additional manure amounts.

10. THE IMPORTANCE OF GROWING FODDER GALEGA

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Galega as a legume crop improves physical and agrochemical qualities of soil. Nodule bacteria *Rhizobium galegae*, being specific, are very productive and enable to fix nitrogen over 300 kg per hectare.

Galega has excellent adaptability to soils. It does not tolerate only too acid soils or areas with staying surface water. Due to long persistence it suits well for cultivating heavily cultivable land and for lands left without any crop cultivation for a long time.

Galega is a tap-rooted herb with a strong and extensive root system which enables the economic use of soil nutrients, accumulation of organic matter into soil and constant increase of soil fertility. It spreads and propagates also by underground stolons which provides natural regrowth of galega and is the basis for long persistence.

The assimilation area of a viable plant cover is big (14…15 m^2 per 1 m^2 of soil), the location of vegetative organs on the plant is rational and it provides effective use of sunlight. The assimilation of plants´ lower leaves lasts until flowering.

Galega is high-productive on non-acid sod-calcareous and sod-podzolic soils (7…10 t ha^{-1} DM) and the yield is protein-rich (20…22% in DM). Unlike many other fodder plants, galega field starts to give maximum green material yield only since the third-fourth year of growing and after that its productivity is high and stable for a long time (up to 10 years). Therefore the fresh material production from the first years of growth cannot be compared, e.g. in case of clovers and galega, because the advantages of galega growing appears only in years.

After the first cut the regrowth is fast – a new shoots develop also from buds located on root crown and on rhizomes. Fast regrowth spends a lot of reserves which restoration takes time and therefore galega is not suitable either for constant grazing or many cuttings. In case of two-cutting utilisation system the yield of the second cut forms approximately 1/3 from the first cut yield and it can also be harvested in late autumn.

The first cut can be used either for making protein-rich silage of for making hay. Unlike the other herbage legumes, galega leaves do not fall when hay is drying, maintaining good protein content in fodder. The yield from the second cut is suitable for ensiling, green fodder or grazing.

In Estonia the area under galega has remained within the limits of 5000-6000 ha, locating all over the republic. Galega fields can be found both in the islands and hilly landscape of southern Estonia but galega is most sown in mid Estonia. Farmers have learned the peculiarities of galega´s agrotechnology and seed growers are capable of supplying farmers with seeds.

There has been enough seeds also for export. It has been sold to neighbouring republics (Russia, Latvia, Finland) and further (Canada, Japan, etc.).

Galega growing has taken a certain place in Estonian grassland husbandry. Regarding the growth area it ranks third among herbage legumes after clovers and lucernes but annual good seed yield enables to enlarge the growth area.

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