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Review

Fodder Galega—A Versatile Plant

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Abstract: Fodder galega is a perennial, wintering plant, which in recent years has been gaining popularity, mainly because of its useful characteristics. Many researchers have noted its large yield potential and exceptional adaptability to various environmental conditions. The purpose of this study was to collect the most up-to-date knowledge about this valuable plant, a member of the Fabaceae family. Green fodder, especially that made from young plants, possesses very good biochemical parameters which allow it to be used in the nutrition of animals including poultry. Plantations of fodder galega can be set up on highly diverse soils, and in all systems of management. The yielding potential of this plant is appreciated on all farms: organic, extensive and conventional ones. Many scientific studies have demonstrated the usefulness of fodder galega for the protection of farmland that is periodically excluded from farming. In recent years, reports have been published suggesting the high potential of this plant for the acquisition of inexpensive energy from its biomass. Moreover, many scholars have emphasised the medicinal applications of fodder galega. The advantages of the cultivation of fodder galega are (1) its low nutritional requirements; (2) a lack of threats from the specialised pests; and (3) its positive effect on soil fertility. It is recommended that areas having undergone several years of fodder galega cultivation act as very good forecrop for plants with high nutritional requirements.

Keywords: *Galega orientalis* Lam.; chemical composition; energy; fodder; medicine; fallow land

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1. Introduction

Formerly, the family of Leguminaceae included the genus Galega, which traditionally comprises the plant commonly called 'goat's rue'. There are two known species: *Galega officinalis* Lam.—an ornamental and medicinal plant, which grows as a weed in South America, New Zealand and Central Europe—and *Galega orientalis* Lam.—a perennial leguminous plant which has been the subject of numerous experiments and has been grown as a valuable fodder plant in Estonia since 1972 (Figure 1).

Figure 1. Fodder galega in late May (Żarczyński 2003).

Once the high yielding potential of *Galega orientalis* achieved under the temperate climate conditions prevalent in Estonia and Scandinavian countries was documented, the Estonian Research Institute of Agriculture and Land Improvement applied to the International Seed Testing Association for the plant to be registered. Consequently, the species was listed as a field fodder plant under the name of fodder galega (*G. orientalis*)—also known as eastern galega. This name was chosen to avoid confusing it with the other species, *G. officinalis*, which is toxic to ruminants due to its content of several alkaloids, including vasicine and galegine [1–3]. Nowadays, fodder galega is classified as a member of the family Fabaceae, the subfamily Fabaoideae, and the known cultivars are Gale, Speranta and Risa [4–6]. As a fodder plant, it is commonly cultivated in Estonia, Finland, Latvia and Russia [7]. Therefore, this study aimed to collect the most up-to-date knowledge about this valuable plant.

2. Origin and Botanical Traits

Fodder galega (*Galega orientalis*) is a perennial species, originating from the Caucasus [8]. Its natural habitat is that of the woodland submountain regions of Armenia, Georgia, Dagestan and Azerbaijan, growing at altitudes between 300 and 1800 m above sea level. The characteristics of the plant developed under such conditions have been successfully preserved and maintained, hence the varieties grown today can withstand winter temperature drops down to −25 °C with no snow cover and down to −40 °C under snow cover, as well as spring frosts down to −6 °C, with no negative effect on their yields [9]. Fodder galega is an herbaceous perennial plant with pinnately compound, dark-green leaves (Figure 2). The share of leaves in the aerial mass can reach up to 40–70%, obviously depending on the developmental stage. Leaves are set on stems growing 40–150 cm tall; the stems are more or less bent at nodes, branched or naked, with scattered, short white hairs. Lateral branches grow from nodes on the main stem. Rooted rhizome shoots appear in the spring, giving rise to new branches, which eventually grow roots and become new, independent plants. Stipules grow up to 5–20 cm in length; leaves possess 5–10 pairs of leaflets, 1.0–4.0 cm in length and 0.4–1.5 cm, having a longitudinal, linear lanceolate shape. An inflorescence of length between 8 and 27 cm is an elongated bunch composed of 25–75 flowers, which are almost blue or purple—or less often, white—in colour. The plants fully blossom a year after plantation is started. The fruit of fodder galega is a multi-seeded, non-splitting pod, which holds 5–8 kidney-shaped seeds, which are yellow-green in colour and turn brown as the seeds mature. The seeds are 2.5–4.0 mm long and 1.7–2.0 mm broad, and when fully mature they are smooth and matte—as shown in Figure 3A [4,10]. Galega seeds mature quite early, usually two weeks earlier than the seeds of lucerne or red clover [1,3].

Galega orientalis is a plant with an exceptionally well-developed root system, composed of a deep taproot, growing down into the soil up to 1 m, while the lateral roots grow up to 70–80 cm. Many researchers [11,12] maintain that this root system enables the plant to not only have good access to water and nutrients, but also secure a good plant stand in a field. Fodder galega can multiply and spread in two ways: by vegetative reproduction, sending underground stems; and generative reproduction, through seeds which need to be inoculated with the bacteria of the genus *Rhizobium*. Inoculation secures higher yields. Owing to the presence of the *Rhizobium* genus bacteria (Figure 3B), the seed yield is much higher and of better quality [13]. Fodder galega is characterised by slow growth during the first year, with only some of the plants blossoming in the late summer or in autumn. However, starting from the second year, the plants enter a period of abundant growth, which they owe to their highly efficient fixation of atmospheric nitrogen, their easy uptake of nutrients from the arable and sub-arable soil horizons and the lack of specialist agrophages [14–16].

Figure 2. Fodder galega before the third cutting (Żarczyński 2021).

The long vegetative season of fodder galega, according to many authors, is a factor that contributes to its production of considerable volumes of biomass [17]. However, the key role is claimed to consist of the extremely efficient fixing of atmospheric nitrogen by nodule bacteria symbiotic to the plant. As reported by Nõmmsalu et al. [18] and Meripõld et al. [19], fodder galega is able to accumulate from 180 up to 480 kg N/ha a year.

A **B**

Figure 3. Fodder galega: (**A**) seeds; and (**B**) root nodules (Żarczyński 2021).

The purple and pink colours of the flowers and the highly intense blooming of the plants, which usually begins during the last ten days of May and continues until the end of June, improves the visual appeal of the site where fodder galega grows. This explains the increasing popularity of fodder galega as a horticultural plant [20]. The species produces abundant amounts of nectar, thereby being a valuable bee forage for honey bees and other insects [8]. The plant can be maintained cost-free during many years and each year it is able to produce robust inflorescences as well as provide shelter to many pollinating insects, small birds and even some larger mammals such as deer or hares. Fields of fodder galega, pure or mixed with awnless brome, are a welcome addition to a landscape (observations made by the authors of this paper during the period 1996–2010) and is a suitable plant for the 'greening' of vacant plots.

3. Agronomic Technology

Fodder galega, similarly to most small-seeded fabaceous plants, requires very careful soil tillage prior to sowing. Because this species develops slowly during the first year, it is recommended to ensure that a field intended to be sown with fodder galega be cleansed of weed diaspores to the highest extent possible. It is also recommended that fodder galega is grown alongside another plant for protection during the first year. Additionally, to protect it from weeds during the first year of growth, it is advisable to apply herbicides in the conventional farming system; whereas in organic farms, it is recommended to sow some 10 kg/ha more seeds and then to perform mechanical weeding [19]. The seeds used for sowing must be either mechanically or chemically scarified as this enables much better plant emergence rates. To achieve good plant density from pure sowing, it is necessary to sow approximately 20–30 kg of seeds per hectare, i.e., 300–500 seeds/m^2, to a depth of 1–2 cm, in rows spaced at 12–60 cm. When fodder galega is grown in a mixture with grasses, weed control is typically ensured by parallel rows of grass [21].

Numerous studies have demonstrated that fodder galega yields well in various types of soil with a pH ranging from slightly acidic to alkaline [22,23]. Prior to sowing the seeds, it is recommended to apply up to 30 kg N/ha to the soil, i.e., a starter dose of nitrogen [24]. A study conducted by Sienkiewicz et al. [25] showed that fodder galega responds well to phosphorus and potassium fertilisation. The authors deemed it reasonable to supply the

soil annually with approximately 20 kg P and 65 kg K per 1 ha. Nitrogen fertilisation in addition to the starter dose is considered unnecessary, and the application of this fertiliser component leads to the depressed growth rate of the whole galega plants and lower yields due to the progressive death of root nodule bacteria. For environmental reasons, one should avoid a situation where mineral nitrogen accumulates excessively in soil [26]. The research completed by Adamovich [27] suggests that nitrogen fertilisation improves the quality of fodder galega green matter, which in turn enhances its fodder value. Directly before sowing, fodder galega seeds need to be inoculated with the bacteria of the genus Rhizobium; alternatively, these bacteria should be introduced earlier into the soil. Seed inoculation with an appropriate strain of bacteria, can result in a nearly two-fold increase in fodder galega dry matter yield. This treatment has a considerable effect on the quality of the harvested yield, in addition to which it largely influences the yield quality [13]. Andrzejewska and Ignaczak [28] demonstrated that when galega seeds were inoculated with the *Rhizobium galegae* genus bacteria, the harvested biomass of galega contained more nitrogen, phosphorus and magnesium. When growing fodder galega for seeds, it is possible to obtain a yield of 170–598 kg/ha of seeds [19,29]. The yield of seeds mostly depends on weather conditions, particularly the amounts of rainfall, as well as on the presence and number of pollinating insects on a given site [30]. There is yet another benefit from growing fodder galega: even if it is cultivated on the same field for over a decade, it is not difficult to convert this field for other uses afterwards. According to Ignaczak and Szczepanek [31], fodder galega grown for several years can serve as a good preceding crop for winter wheat. The results achieved by many researchers prove the excellent positive effect of fodder galega on soil fertility, characterised by a considerable increase in the soil content of organic carbon, nitrogen or available forms of nutrients, even when the galega plantations have not been fertilised [23,26,32]. A site after fodder galega is considered to be free from pathogens and rich in nutrients (especially nitrogen), which are the factors directly responsible for the yield of subsequent crops [15,31].

4. Fodder Use

The yielding of fodder galega has been well studied in many European countries. Following the research results found by many scientists [1,3,27], it may be concluded that the yielding advantage of this crop over other perennial leguminous plants, such as lucerne or clover, increases with a more northerly location of the growing site in Europe. The harsher the conditions for the growth and development of galega, the more productive it is in comparison to species which are less adaptable, e.g., lucerne or clover [17]. The plant is also suited for cultivation under the severe conditions of North America. Studies conducted over a vast area in Canada confirmed its fodder suitability, and the results suggest that the yielding productivity of galega is on par with lucerne or red clover [33]. Similar reports have come from Japan, where the plant produced more stable yields than lucerne or red clover under the harsh conditions of Hokkaido [34]. *Galega orientalis* is recommended by many researchers as a highly productive fodder plant of very high nutritional value [27,35–38]. One of the reasons for its high productivity, which reaches 80 tons of green matter per 1 ha annually, is its high adaptability to a new environment and good yielding even under the adverse distribution of precipitations during the plant's growing period [39]. The research demonstrated that the increased productivity follows from a very compact sward, which fodder galega is capable of developing and maintaining for several years [1,4,22]. Another advantage of this species is its high daily growth, which may even reach 4 cm per day under favourable conditions [5]. Moreover, it should be noted that no other plants have been observed in a field cropped with galega for several years, which according to Żarczyński and Sienkiewicz [14], has a positive effect on the biomass yield. Fodder galega grown for fodder should be mowed during the first days of flowering, which ensures its higher nutritional value and the best proportion of protein yield to total plant yield (Table 1). Biannual mowing is recommended, as mowing three or four times a year results in a lower yield. Delaying the harvest date, particularly the time of the first cut,

leads to the rapid deterioration of the fodder's nutritional value [17]. The fresh fodder of galega is rich in protein, macro- and micronutrients, vitamins (especially vitamin C) and carotene (Table 2). This is why it is suitable for both direct grazing and for the production of dried fodder, hay and silage.

Table 1. Recommended terms of sowing and harvesting for fodder galega [17].

Month	The First Year
April	Sowing with a protective plant, such as oat or barley
July	Only one cutting
Other months	Plant regeneration
	The Second Year and Beyond
May/June	First cutting (80–130 cm) *
August	Second cutting (50–60 cm) *
September	Third cutting (30–90 cm) *

*—plant length.

Table 2. Chemical composition of fodder galega (*Galega orientalis*).

Ingredient		Content	Source
Crude protein	g/kg DM	197.7–295.0	[27,35,40,41]
Crude fat	g/kg DM	29.5	[35]
Crude fibre		245.8	
Lignin		37.0	
Crude ash	g/kg DM	86.2–124.8	[35,40]
P	g/kg DM	2.1–4.8	[14,35,40]
K		28.1–31.7	
Ca		12.4–17.5	
Mg	g/kg DM	2.3–3.6	[14,20,27,40]
Na	g/kg DM	6.1	[40]
Si		2.1	
Cu	mg/kg DM	4.5–8.0	[20,35,40]
Fe	mg/kg DM	80.0–100.0	[20,35]
Zn	mg/kg DM	15.0–30.6	[35,40]
Mn		12.0–83.8	
Ni		0.59–1.87	
Cr		0.76–0.95	
Cd		0.059–0.15	
Pb		0.78–1.37	
B	mg/kg DM	18.42	[40]
Hg		0.012	

The fresh aroma of the fodder encourages its consumption by animals. An advantage of galega in the preparation of hay is that the leaves remain on the stem, which reduces the loss of the most nutritional parts of the plant to a minimum and increases the value of the fodder. A fodder mix for animals may play a pivotal role in the balancing of proteins, as well as in the basic mineral components. The green fodder of this species is characterised by a high content of calcium, potassium and sodium, an optimal concentration of magnesium for ruminants and a relatively low content of phosphorus. The content of micronutrients considered essential in animal nutrition is satisfactory. The iron and manganese present in galega can satisfy the daily demand for these elements in animal nutrition. However, fodder galega has a low content of copper, zinc, boron and nickel [4,20,27,35,40,41].

All of these features of galega green matter make it a highly nutritional fodder, eagerly consumed by cattle, sheep or goats. Recent reports have shown the possibility of using dried fodder galega in poultry nutrition. Adding fodder galega to a feed improves its assimilation, has a positive effect on metabolism and boosts the immune system [20,42]. As reported by Baležentienė and Mikulionienė [35], *Galega orientalis* is a more valuable fodder than traditional fodder plants, e.g., red clover and timothy grass, during the early stages of growth (i.e., during budding and early flowering). Owing to the high content of total protein, which reaches 231 g/kg of dry mass, and the presence of some amino acids (aspartic acid, glutamic acid, phenylalanine), the green fodder of fodder galega may be used as a replacement for the post-extraction soybean meal [35,36]. The content of exogenous amino acids in the protein of fodder galega ranges within 30–46%, depending on the developmental stage of the plant. There is evident correlation between the concentration of particular amino acids and the time of the regrowth of particular swaths. The amino acid content of protein in galega green fodder is comparable to that of red clover and does not substantially differ from lucerne. As it is a protein-rich plant, low-moisture fodder galega silage can be successfully added to maize silage in a feeding ration for dairy cows. Its share in a fodder mix does not reduce the milk yield of dairy cows [37]. Adamovich [27] reported the positive results of feeding fodder galega to heifers. He determined the daily body gain of heifers to be 634 g/day (free range) and 863 g/day (box stalls—closed system). Compared to animals fed with grass silage, green galega silage produced higher daily gains by 70 g/day (free range) and 61 g/day (box stalls—closed system). According to Møller and Hostrup [43], the average concentration of digestible energy, both in energy and feed units, in fodder galega fed to cattle was similar to the energy concentration in red clover, winter vetch and yellow lupin, but lower than in white clover. The negative properties constraining the share of galega in fodder include a high content of crude fibre, neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) [41]. In turn, the high concentration of calcium in galega may lead to hypercalcemia in animals [40].

5. Use in the Protection of Fallow Land and Contaminated Soil

Fodder galega is highly recommended for the multiannual protection of valuable land for farming, as well as for the reclamation of degraded land [26,32,44]. The usefulness of fodder galega has also been confirmed in monitoring and controlling environmental hazards resulting from petroleum-derived substances, e.g., heating oil [45].

According to many authors [11,30], the lush and rapid growth of fodder galega from the second year of cultivation and its high density contributing to weed control may have significant importance in managing fallows. The authors cited above reported a relatively low sensitivity of this plant to weed infestation and its ability to develop a substantial mass underground which contributes to soil improvement. Hence, the plant can be successfully sown both on its own and in mixtures with grasses (Figure 4). In both cases, a field of galega or its mixtures with brome grass covering fallow land is characterised by remarkably long sustainability, especially during further years of growth [11]. Another advantage of this plant is its good adaptability to various, often changeable, habitat conditions [1]. According to Oldham and Ransom [46], fodder galega is a species whose growth is often invasive in character. Żarczyński and Sienkiewicz [14] noticed that an excellent way to protect land temporarily out of cultivation is to maintain fodder galega, which produces a large amount of both green and dry mass. A mixture of fodder galega and awnless brome will, according to the authors, produce slightly less biomass annually. It should be noted that both fodder galega and a mixture of fodder galega and awnless brome may be recommended, in the authors' view, for the temporary management of valuable land out of cultivation. According to Tonitto et al. [47] the organic matter produced by fodder galega may yield similar results to manure, especially in terms of nitrogen supply in the soil. To prevent the accumulation of an excessive amount of mineral nitrogen in the soil, it is advisable to cover fallow land with a mixture of galega and grass. This type of mixture also reduces the emission of N_2Ox into the atmosphere [48]. Research by Żarczyński and

Sienkiewicz [14] demonstrated that both fodder galega and its mixture with awnless brome are capable of accumulating considerable levels of macronutrients. To a certain extent, this is a consequence of the large amount of biomass produced by galega in the first year [32]. The high productivity of both the aerial organs and the well-developed and spreading root system ensures a potential source of organic matter. The cited researchers concluded that a few years of fallowing the land under fodder galega entailed the systematic accumulation of organic matter in the fallow land. Turfing fallow land with fodder galega helps to improve the concentration of valuable macro- and micronutrients [23,25,49,50]. According to Sienkiewicz et al. [25], fodder galega has a strong root system, which enhances the assimilation of nutritional elements from the soil's natural supply. All of these properties of galega mean that fields sown with this plant are enriched with total nitrogen and organic carbon, while the availability of other nutrients is also improved [32,49,51].

Figure 4. Fodder galega + *Bromus inermis* in late May (Żarczyński 2003).

Fodder galega has been successfully used to reclaim land contaminated with petroleum derivative substances [44,52]. Galega is recommended for use in a mixture with awnless brome and in this combination can produce a crop yield 30% higher than that yielded by fertilised brome. Fodder galega has a high phytoremediation potential. The contamination of soil with toluene did not cause fluctuations in the development of fodder galega or in the viability of rhizobia [53]. Fodder galega also demonstrated the good growth, nodulation and nitrogen fixation as well as the ability to develop strong rhizosphere in soil contaminated with heating oil.

6. Energy Use

Fodder galega has been recommended as a productive and sustainable energy plant by many researchers [6,24]. This species is able to produce a large amount of dry matter, which is one of the basic requirements for energy plants. Among the many advantages of this species, researchers have emphasised two: namely the consistently high productivity and the generation of energy at a relatively low cost of fertilisers, which follows from the symbiotic relationship of galega with nodule bacteria. The calorific value of 1 kg of dry matter ranges within 16.7–18.7 MJ, being comparable to sweet sorghum, miscanthus, straw, tree bark and lignite. The use of galega biomass as a source of renewable energy does not cause such high emissions of SO_2 and NOx as when burning hard coal [24,48,54].

Except for the incineration of the biomass, good economic effects are also obtained from the gasification of fresh or silaged galega, with the gasification of fresh plants providing better results [12,13,54]. The composition of ash after galega incineration has been

identified. It contains a substantial amount of potassium and calcium, and slightly less magnesium and phosphorus. This ash can be successfully used for the fertilisation of many crop plants [24].

Same as in fodder crop management, the seeds of plants cultivated for energy must be inoculated. According to Kalembasa and Symanowicz [13], this may produce an average of 1.9-fold more energy in comparison to plantations where Rhizobium galegae was not used. Sowing galega in mixtures with grasses facilitates the assimilation of nutrients, increases the share of dry matter in the total yield of this species, and improves the fermentation properties of the harvested biomass [12]. Even in high-mountain locations on poor soil deprived of humus, this species produces energy at a level of 115–153 GJ ha^{-1} [21]. Dubis et al. [6] also reported the high calorific value of this plant, confirming the usefulness of fodder galega in both extensive cultivation and with the use of intensification technologies. According to these authors, the gasification of green galega can produce the energy yield 3.7-fold larger than the yield obtained from maize, which partly arises from the lower cost of fertilisation and plant protection. The study by Symanowicz et al. [24] demonstrated that energy plantations must be fertilised (20 kg N, 50 kg P, 150 kg K and 150 kg Ca/ha). The fertilisation regime suggested above nearly doubled the energy efficiency of fodder galega per 1 ha.

7. Usefulness in Medicine

The herbage of fodder galega has been used in folk medicine long before attempts were made to explain how it affected the human body. Today, *Gallega officinalis*, also known as medicinal galega, has a more extensive use in medicine, but research shows that *G. orientalis* may also been used in medical treatments. An analysis of the composition of this plant indicates that it is rich in ascorbic acid, carotene, alkaloids and macro- and micronutrients, thereby being useful in medical treatment [24,55,56]. Further research shows that *G. orientalis* has properties which regulate the sugar metabolism of the organism [57,58], Guanidines contained in galega are responsible for the hypoglycaemic effect, as they help improve the sensitivity of peripheral tissues (including skeletal muscles and liver) through the activation and membrane translocation of GLUT1 and GLUT4 transport channels. Guanidines inhibit gluconeogenesis, seem to have an impact on the lipid profile of patients, reduce cholesterol and triglycerides, and because of their diuretic properties, lower blood pressure. Guanidines served as precursors of antidiabetic agents, for the treatment of Type 2 diabetes or insulin resistance. Because of its composition, galega has been identified as an herb with anti-bacterial, anti-inflammatory, antioxidant and lactation-stimulating properties [59–61]. Good antioxidant activity has also been identified in the extracts of galega seeds [62].

8. Knowledge Gaps on Fodder Galega

Perspectives for further research in the field of fodder galega should focus on:

1. Examining the properties of the root system, allowing for a better utilisation of nutrients;
2. The determination of suitability for fodder use in mixtures with grasses, especially in the system of extensive organic farming;
3. Energy use of the fodder galega biomass not only from the monoculture of this plant, but mainly in mixtures with grasses;
4. Examining the possibility of gasification of this plant, its mixtures with grasses or other energy sources and determining the fertilisation value of the resulting digestate;
5. Defining the research on the subsequent impact on the yield of agricultural plants.

9. Conclusions

Fodder galega is a durable, perennial species belonging to the Fabaceae family. It is characterised by slow growth during the initial growth period, however, in the following years of cultivation, it shows a high yield potential. The long-term studies on creative

breeding allowed to obtain various varieties of this species that meet expectations in terms of fodder and energy use, as well as in the protection of fallow land or the reclamation of contaminated land. The cost of obtaining biomass, protein or energy from fodder galega is relatively low due to the possibility of symbiosis between this plant and nodule bacteria. Research into the medical applications of this plant is defined as developmental. In view of the changing approach to biodiversity, including the protection of animals (especially pollinators), the cultivation of this plant may be recommended. Increasingly, there are opinions that fodder galega will have a very good chance of entering the framework of the new European green deal. The low nutritional requirements of this species and a lack of threats from specialised pests may encourage the cultivation of this plant on a larger scale than at present. Furthermore, another great advantage of this plant is its very positive effect on soil fertility. After several years of cultivation of fodder galega, such sites can be considered as very good forecrop and can be used by plants with high nutritional requirements.

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