

Growing technology and production costs for dry mass for direct burning and green mass for biogas of *Galega Orientalis*

T. Võsa and H. Meripõld

Estonian Research Institute of Agriculture (ERIA),
Teaduse 13, Saku, Harjumaa 75501 Estonia;
e-mail: taavi.vosa@eria.ee, heli.meripold@eria.ee

Abstract. Demand for local and renewable energy source materials is accelerating the search for new crops for energy production. Goat's rue or galega (*Galega Orientalis Lam.*) is known as a long-living and well-adapted rhizomatous legume used mainly for production of high quality forage. Thanks to its strong stem and nitrogen-fixing bacteria, an economically produced and harvested yield is feasible. As an energy source, its yield can be used in an alternative manner. In this paper estimated usage is based on a combination: direct burning of dry material (spring harvest) and ensilaging of summer harvest. Therefore the crop produces 2 yields and gives the best estimated yield. Calculations for production costs are made for pure crop and mixed grasses, since these mixes are most productive. Hauling to the usage site and costs related to material processing are not considered. Results show that establishing of the crop for pure stand and mix with grasses will cost 467.88 and 487.06 €ha⁻¹, yearly costs are 378.56 and 421.81 €ha⁻¹ respectively, crop finishing adds extra 111.38 €ha⁻¹ in both cases.

Key words: *Galega Orientalis*, bioenergy, growing technology, technological chart, production costs

INTRODUCTION

Estonia, like most countries, has ratified the Kyoto Protocol, which requires us to reduce our greenhouse gases emissions. This can only be done by combining different measures: reducing overall energy consumption and using more local energy sources, especially renewable ones. Though energy saving is the most powerful weapon against the growing energy demand, this target is very difficult to achieve on the national level, as people like their way of life. However, another possibility, currently attractive for politicians, is local production of renewable materials.

Agriculture and forestry are the main sources for such material. For sustainability it is crucial to find crops for energy purposes which are not competing with conventional food or feed crops within the growing area. Productive field area is limited and therefore it is important to assure food and feed production first (Yamamoto et al., 2001). Since herbaceous plants are very fast growing, flexible in crop rotation plans and can function as pioneer plants, these plants are promising. Energy source materials usually have lower quality requirements than food or feed industry inputs. This allows farmers to use less fertile or otherwise problematic (small area, bad shape, water problems) fields for raw material for energy production.

Goat's rue or galega (*Galega Orientalis Lam.*) is known as a long-living and well-adapted rhizomatous legume used mainly for production of high quality forage for agricultural ruminants in Estonia. Galega has two key properties for energy production: good biomass production and low fertilizer demand, thanks to nitrogen-fixing bacteria. It is also suitable for growing with mixtures with other grasses, and also supplies N for them (Raig et al., 2001).

Different crops have been investigated as raw materials for energy production (Lewandowski et al., 2006; Jasinskas et al., 2008). Most research points out that although harvested yield can be used as energy raw material, economical feasibility of this may be questionable.

Crops must be established, maintained, the yield harvested and processed according to requirements of the selected energy production method. The requirements are widely variable, which provides farmers with flexibility to adopt changes but also new problems: what, how and where is the most feasible crop to grow. Only a professional and motivated producer can make correct choices, provided s/he has enough information about different possibilities.

Although chemical composition is of some importance, low moisture content is the main requirement for dry mass burning. Green mass for biogas must be suitable for ensilaging. Biogas yield is highest from fresh material, but high quality silage can yield similar amounts of biogas (Lindorfer et al., 2008).

This paper deals with production costs of galega as raw material for energy production. Neither hauling, preliminary storage nor technological preparation costs are included, since these are case-dependent. Calculations also depend on energy costs, since fuel for tractors is a major expense item. Therefore calculation results, exposted later, are also date-dependent.

MATERIALS AND METHODS

The basis for calculations is found in the technological chart for growing herbaceous plants for feed. This chart is modified to answer slightly different requirements for energy use compared to fodder requirements. These changes bear primarily on harvest time and fertilisation.

Calculations also predict that the crop will be grown on already set-aside or otherwise low value land, which usually requires more tillage and maintenance than is necessary on good quality fields.

The technological chart of galega for energy purposes consists of the following operations:

1. Before establishing crop. These operations are done in previous autumn:
 - a) destroying previous crop and weeds chemically;
 - b) pre-ploughing shallow tillage with disc harrow;
 - c) ploughing. This also can be done in spring.
2. Establishing crop. These operations are done on spring sowing:
 - a) ploughing, if not done in autumn;
 - b) soil tillage;
 - c) removing stones;
 - d) sowing. Both starter fertilizers and seeds are placed in soil.

3. Maintenance:
 - a) weed control. Mowing, where suitable, works well against certain weeds. Chemical application is, however, sometimes necessary.
4. Harvesting and maintenance on next, yielding years:
 - a) mowing and swathing;
 - b) baling (dry) or picking by self-loading silage wagon (green);
 - c) collecting and transporting bales to preliminary storage (up to 5 km);
 - d) fertilizing.
5. Finishing crop:
 - a) chemically destroying plants;
 - b) pre-ploughing tillage with disc harrow;
 - c) ploughing. This can be replaced with shallow tillage but is not recommended.

Harvesting uses conventional hay and silage machinery: balers and silage wagons. Bale collection and local transport is accomplished with forest trailer and lifter, hitched to agricultural tractor. In every season two yields are harvested: dry mass in spring and green mass in summer. Dry mass is targeted to boilers, for direct burning. Green mass is suitable for biogas reactor or for animal fodder. In the latter case, feed quality requirements to ensure safe feedstock must be carefully observed. In both cases silage is preserved in storage buildings or is piled in a special area, not on the field. Bales are round shaped, because this machinery is widely available. (Big square bales are more effective for hauling, but require special machinery.) Logistics, however, is one crucial aspect of the economical feasibility estimation. Collected yield must be hauled to the conversion plant the most effective way, since energy density of herbaceous materials is small. From the logistical point of view, denser and heavier bales are welcome, since more energy can be derived from the vehicle cubage. This also reduces costs for deposition of dry material.

Each operation has 8 indicators. These indicators are either calculated or found from tables for all operations, which are present on the technological chart:

- 1) composition of machines (tractor and work machine) included;
- 2) time for operation;
- 3) estimated productivity;
- 4) machine costs per hour;
- 5) total machine costs;
- 6) estimated expenses for additional materials;
- 7) cost of additional materials;
- 8) total cost of operation.

Total cost of operation is expressed in €ha⁻¹.

Table 1. Estimated yield for crops on calculations.

Material	Yield, kg ha ⁻¹	
	Pure stand	Mix
Dry material for burning	4,000	4,500
Green mass for silaging	20,000	30,000

Galega with nitrogen-fixing bacteria is a good neighbour for some grasses. ERIA has achieved good results with *Phleum pratense* and *Alopecurus pratensis*, so these are included in our calculations (indicated on tables as mix).

The Good Agricultural Practice requires that soil fertility and phytosanitary state cannot decrease during crop rotation. Therefore fertilizing with mineral fertilizers is also included in the technological chart and also in the calculations.

Machine costs are calculated with algorithms of ERIA. These can be downloaded from internet (*Algorithms...*, 2008). Fuel price in calculations is 0.77 €l⁻¹. All prices are calculated as farm prices, VAT (Value Added Tax, 18 % in Estonia) and risk is not included.

Calculations are performed on MS Excel for environment. No statistical analysis is made.

Calculations are made for the typical size of farm producing this kind of material – 300 ha of overall field area, which accords with six field crop rotation. The total area of energy crop is 100 ha (two crop rotation fields). The farm has necessary machines and labor force.

Machine productivity in models is always a problem. This calculation uses data collected on work observations in Estonian farms (not published), verified by machine resellers.

To verify calculations, ERIA has sought out the cooperation of Estonian farmers. Unfortunately they are not yet growing energy galega, but fodder galega instead. These farmers are reporting similar costs both for establishing a crop and harvesting a green mass. Galega for dry mass in early spring is not yet harvested in Estonia on farm-scale.

RESULTS AND DISCUSSION

Calculations based on the technological chart for galega for energy purposes clearly show that although this crop can be farmed without N-fertilizer, it requires still considerable inputs (Table 2).

Table 2. Costs of growing galega as energy crop in pure stand and in mix.

Expense	Cost, €ha ⁻¹	
	Pure stand	Mix
Establishing crop	467.88	487.06
Yearly costs in yielding time	378.56	421.81
Extra costs for finishing crop	111.38	111.38
Estimated production costs on 5 year time	2,302.62	2,522.45

Extra seed and fertilizer rates used on the mixed crop cause a slightly higher cost to establish crops. As shown in table 2, establishing costs on set-aside land are quite high, caused mostly by two additional operations – pre-ploughing tillage and actual ploughing. Any operation related to soil movement is time and energy consuming and thus reflects on costs. Results do not consider mineralisation and soil damage to repeatedly moving, shredding and mixing soil, because these costs are not clearly extractable.

Table 3 shows costs distribution of crop establishment. The most expensive job is seeding, since high quality seed is expensive. Starter fertiliser is an additional cost.

Table 3. Establishment costs of galega as energy crop in pure stand and in mix.

Expense	Cost, €ha ⁻¹	
	Pure stand	Mix
Destroying previous plants	44.20	44.20
Pre-ploughing tillage	24.92	24.93
Ploughing	42.25	42.25
Shallow tillage	25.98	25.98
Stone removal	44.87	44.87
Rolling	18.96	18.96
Seeding	217.57	236.75
Mowing weeds	18.86	18.86
Chemical weed control	30.27	30.27
Establishment costs	467.88	487.07

Another expensive job is stone removal, often necessary on Estonian fields, since stone-less fields are already being farmed for higher value products. Energy crops as pioneer crops in set-aside land suffer from field preparation work. But once this work is properly done, it significantly reduces cost for continuing crops. In calculations this operation is intended to be done by hand-to-tractor-towed wagon.

The most arguable job in technology is chemical weed management in the first (yieldless) year. In various cases this is unnecessary. But, again, energy crops are often the first plants following years of weed growth. It is possible but not guaranteed that first spraying and soil tillage will stop the growth of harmful plants in the crop. Therefore establishing an energy crop without reparation against weeds is not a feasible plan.

Harvesting and fertilizing in yielding years are shown in table 4. Nutrients removed with yield are compensated with mineral fertiliser spread after first harvest, in spring.

Table 4. Harvesting and fertilising costs of galega as energy crop in pure stand and in mix.

Expense	Cost, €ha ⁻¹	
	Pure stand	Mix
Spring harvest (dry mass)		
Mowing and swathing	18.86	18.86
Baling	61.66	63.36
Bale collecting and transport	45.10	45.10
Fertilising	89.72	89.72
Summer harvest (green mass)		
Mowing and swathing	18,86	18.86
Collecting with silage wagon	142,23	183,79
Harvesting and fertilising costs	378.56	421.81

The most expensive job is green mass collecting with silage wagon, since the machine is expensive and the collectable mass is remarkably big. But this harvesting method minimises wastes, because no wrapping film is used and silage quality in larger amounts is also more stable.

All fertiliser is given once a year. This is possible because only nitrogen-fixing bacteria's basic nutrients, P and K, plus micronutrients are needed.

CONCLUSIONS

Rising energy demand is requiring a widening of stock as raw materials for energy production. Galega as a nitrogen-fixing, well wintering, high yield herbaceous plant can be used as a local resource in Estonia. Its long and strong stem is suitable for direct burning and young green plants are well suited to biogas production.

All crops compete for field area. Herbaceous plants can yield well on areas where more advanced food and feed crops cannot. Therefore such plants are suitable for the less quality-demanding industry – energy production. But herbaceous plants have low energy density and therefore it is important to calculate economical and ecological efficiency in every case. Producing a low value stock on high quality field is neither economically nor ecologically efficient. Special attention must be given to logistical aspects (available vehicles, storage places, road conditions, etc).

Galega is growing well in Estonian conditions, among other countries and is one prospective crop for the energy industry. Set-aside lands must be prepared thoroughly before seeding and some additional weed control is required in the first year. If this is done properly, the crop can be harvested for many years.

Costs €per hectare for galega production are as follows:

- 1) crop establishment - 467.88 € for pure stand and 487.06 € for mix with grasses;
- 2) yearly costs in yielding time - 376.44 € for pure stand and 421.81 € for mix with grasses;
- 3) extra costs for finishing crop - 111.38 € for pure stand and 111.38 € for mix with grasses;
- 4) estimated production costs for 5-year harvest time – 2,302.62 € for pure stand and 2,522.45 € for mix with grasses.

Costs are noticeably large and markets for energy hay or energy silage still low. Therefore growers need to calculate if it is economical to grow galega for energy purpose or to continue to use it as feedstock.

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