HERBACEOUS PLANTS UTILIZATION FOR BIOENERGY PRODUCTION

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ABSTRACT. *In comparison with other countries, in Estonia the research work related to herbaceous energy cultures is in the beginning. Here is missing clear overview of cultures that could be cultivated in Estonian conditions for energy production. Also it is not evident which technology is best in order to get bioenergy from grasses in Estonia. In Finland and Sweden generally used technologies might not be justified in local climatical conditions. In Estonia, the spring harvest for energy hay could be problematic because of rainy springs. The spring harvest scarcity is also the harvest losses and small number of suitable species for particular method. It is possible, that in Estonian conditions the most suitable bioenergy type could be biogas production, in comparison to energy hay production this does not set so strict requirements for substrate quality and therefore the most herbaceous species are useful for this.*

Keywords: *Bioenergy, sward types, sward duration, grasslands.*

Introduction

A key issue concerning the sustainable development of a country is the energy sector. Strategic documents in the European Union (EU) emphasize that the main factors concerning the energy sector are the rapid increase of renewable energy resources and their relative importance compared to the future usage of current energy sources. The current belief is that the EU's dependency on imported fossil fuels is linked to an increasingly significant economic security risk which will cause a slow-down in the rate of economic development. Estonia, as a new EU member state has good preconditions for the broad use of renewable energy resources. The production of biomass is becoming more efficient as the relevant technology is continuously being developed. In 2005, renewable energy sources comprised about 12% of the primary energy supply, which was mainly wood fuel. Despite Estonia's small land area – 45,226 km^2, the equally small population of 1.4 million means that the ratio of area for crop cultivation per person is in EU context relatively high at approximately 0.4 ha per person.

The land resource for herbaceous plants in an Estonian context

The area of Estonian farmland has, during the last few decades, shrunk through general abandonment by about 25–30%. This abandoned agricultural land, up to 300 000 ha, could be exploited for bioenergy crops' cultivation, although this land is of varying quality and the exact type of area that can actually be used for successful crop production is unclear. The use of abandoned farmland would be strategically correct since, the management of natural resources is increasingly critical and the employment rate in economically underdeveloped areas would be increased and the security of the national economy would be enhanced.

There were, in 2006, 840 000 ha of land subject to different agricultural supports, of which 155 000 ha are grasslands under 5 years of age including red clover-timothy leys in field crop rotation. 140 000 ha consists of sown grasslands or so called permanent grasslands over 5 years of age. Semi natural grasslands comprises 145 000 ha. There are altogether 440 000 ha of different grasslands. The land resource for abandoned fields is 200 000–270 000 ha. The feed for productive animals (cattle and sheep) is produced mainly from 295 000 ha. Some of the yield from semi-natural grasslands is used but none of the biomass is used in set-aside (abandoned) fields.

The research work related to herbaceous species' utilization potential

Current research work carried out in Europe and USA is directed at determining potentially suitable grass species for bio-energy (Lewandowski *et al*., 2003). The main basis for selection is the productivity of species. As a result of research 35 species have been chosen in USA and 20 species in Europe that could have good potential for bioenergy production of which switchgrass (*Panicum virgatum*), reed canary grass (*Phalaris arundinacea*), gigant reed (*Arundo donax*) and silver grasses (*Miscanthus spp*.) are the focus of attention (Lewandowski *et al*., 2003). Two of these, reed canary grass (*Phalaris arundinacea*) and gigant reed (*Arundo donax*) could, according to their C_3 photosynthesis trait be suitable in Estonian climatic conditions. The gigant reed is not known in Estonia and consequently the cultivation data in local pedoecologial conditions are not available. Some experiments (Eilart, Reidolf 1987; Annuk, 1979) have been carried out in Estonia on the suitability of reed canary grass for feed production. These experiments have revealed that an annual regime of fertilization of 200 kg N ha^{-1} and two cuts will maintain the sward and resulting dry matter yield for reed canary grass at 9–10 t ha^{-1} for at least ten years. Feed production experiments carried out in the 1980s have shown that the sward of other species can also endure Estonian climatic conditions for periods greater than ten years; smooth brome (*Bromus inermis*), cocksfoot grass (*Dactylis glomerata*), tall fescue (*Festuca arundinacea*) and oriental goat's rye (*Galega orientalis*) (Rand, 1981; Koitjärv, 1986; Lillak, Selge, 1990) (Table 1). The suitability of these species, for both biogas production and burning, needs to be experimentally controlled.

Table 1. Grasslands productivity in Estonia depending on plant species in optimal plant growth conditions
Tabel 1. *Rohumaade produktiivsus Eestis sõltuvalt optimaalsetes kasvutingimustes kasvanud taimeliikidest*

Plant species *Taime liigid*	N kg ha^{-1}	Optimal number of cuts *Optimaalne niidete arv*	Sward duration, years (in average) *Koosluskestvus aastates (keskmiselt)*	Suitable soil *Sobiv muld*	Dry matter yield/ t ha^{-1} (in average) *Kuivaine massi saak t ha^{-1}*
Phleum pratense	170	2 (3)	4–6	M; P*	8–9
Festuca pratensis	170	3	4–5	M (P)	7–8
Festuca arundinacea	200	3	>10	M (P)	9–11
Dactylis glomerata	200	3	>10	M	9–10
Phalaris arundinacea	170	2	>10	P; M	9–10
Bromus inermis	170	2	>10	P; M	8–9
Alopecurus pratensis	170	3	6–8	P; M	5.5–6.5
Lolium perenne	170	3	3–4	M	7–9
Trifolium pratense	0	2 (3)	2–3	M	9–10
Medicago sativa	0	3 (2)	4–5	M	8–9
Galega orientalis	0	2	>10	M	8–9

* M – mineral soil / *mineraalmuld*
P – peat soil / *turvasmuld*

Estonian research is aware that the qualitative requirements for herbaceous feed and biomass production for bio-energy purpose are different, especially for energy grass, and are even contradictory. The high content of mineral elements in herbaceous plants is, for example, especially important whereas in energy grasses this mineral content should be minimized, because it is related to the ash content that remains in the furnace after burning.

Several research experiments indicate that the optimal time for energy grass harvest is in the following year, after yield formation in early spring (Landström *et al*., 1996). The yield does not need any 'after drying' at this time of year. Moreover, the mineral elements content that causes high ash content is smaller in spring plants than in autumn plants (Landström *et al*., 1996; Burvall, 1997; Mortensen, 1998). Furthermore snow cover is a key reason for yield losses that are due to lodging. These yield losses are arguably higher than the amount of energy that could be used during the autumn for the yield drying. The yield losses during the winter are different according to the herbaceous species' straw strength. Therefore, the rationale would be the usage of different harvest times according to the species properties. Furthermore the precipitation rates in the spring months in Estonia are generally quite high and as a result the ground defrosts more quickly than in Finland. Consequently, as spring harvests may not be suitable in Estonia, alternative harvest times need to be available. However there is a serious disadvantage in utilising only one cut a year as the full yield potential of the grasses is not realised.

Data from several studies reveal that the yield potential will be most effectively realized with two to three cuts during the vegetation season (Eilart, Reidolf, 1987). Plant competition and the duration of plant cover is dependent on the number of cuts. Two cuts maximum, for example, is beneficial for reed canary grass whereas three to four are beneficial to the competitiveness of tall fescue. The first cut may, in the plant development stage, aid the development of subsequent plant cover duration (Annuk, 1979; Lillak, 1989). To lengthen the duration of plant cover could be important for the combined use of herbage: the first cut would be used for the energy grass, and the second would be used for biogas production or feed.

So far research works with energy grasses are based in the comparison of monocultures. Less attention is paid to graminea and legumineous mixture sowings. But in these mixture sowings, the symbiotically bound nitrogen should allow for a reduction in the costs for fertilizers and therefore, the cost of produced biomass. Moreover, if the requirement is for both lengthened plant cover and high yield potential then the gramineae could be mixed with fodder galega (*Galega orientalis*) (Table 2).

The Lithuanian Agricultural Institute (LAI), to date, is the only institution to have studies this question in the bio-energy context. LAI experiments revealed that from a basis of N 120 kg ha^{-1} the monoculture of reed canary grass gave 9.3 t ha^{-1} dry matter and smooth brome in average 7.8–8.3 t ha^{-1}. The best yield results for gramineae / fodder galega was for reed canary grass 7.0–9.1 t ha^{-1} dry matter followed by smooth brome 6.3–6.4 t ha^{-1} dry matter. The dry matter yields of grass mixes with gramineae ranged between 4.8–7.4 t ha^{-1} (Kryževiciene, 2006).

Table 2. Grassland yield in Estonia depending on grass mixtures according to optimal plant growth environment
Tabel 2. *Rohumaa saagikus Eestis sõltuvalt rohusegudest optimaalsetes kasvutingimustes*

Mixture *Segud*	N kg ha^{-1}	Optimal number of cuts *Optimaalne niidete arv*	Sward duration, years *Koosluskestvus aastates*	Suitable soil *Sobiv muld*	Dry matter yield t ha^{-1} (in average) *Kuivaine massi saak t ha^{-1}*
Fodder Galega and Grasses *Söödagaleega ja kõrrelised*	0	2	>10	M*	8.5–9.5
Alfalfa and Grasses *Lutsern ja kõrrelised*	0–70	3	4–6	M	8–9
Red clover and Grasses *Punane ristik ja kõrrelised*	0–70	2 (3)	2–3	M	8–10

* M – mineral soil / *mineraalmuld*

The herbaceous species potential for biogas production

Biogas production is possible from herbaceous biomass that is mixed with different organic materials like sludge, animal and plant wastes and wastewater sludge. All agricultural crops can be used for biogas production. In Germany biogas is produced mainly from a mixture of maize silage and sludge. The suitable C:N ratio (carbon to nitrogen ration) in grasses should be 15–30:1, the best ratio is 18–23:1 and consequently perennial ryegrass (*Lolium perenne*) is widely used in UK. Biogas output is significantly smaller from old and ligneous grasses.

The main factors influencing biogas potential and actual output are the plant species, growth conditions and fertilization and the development stage at harvest. The fermentation is stable and effective if grass silage is used for substrate instead of raw grass. In the fermentation grass and sludge mixture the biogas yield is equal to the percentage of grass organic matter (OM). The biogas outcome (CH_4+CO_2) in grass OM to one kilogram of grass dry matter is on average 0.55–0.65 m^3, including methane 0.23–0.35 m^3. On average biogas contains 55% methane (fluctuations 42–69%).

In Estonia research concerning biogas production is just beginning. The lack of suitable laboratories has so far hindered research development. This will change with the improvement of facilities at two centres – the Estonian University of Life Sciences in Tartu and Tallinn Technical University – which will enable research into biogas production. The plan is to use the facilities at the Estonian University of Life Sciences to run a series of experiments to identify which plant species are most suitable for bio-gas production and burning. This programme will include not only those species identified by other national research studies as suitable for both purposes, but also the grassland cultivates of grasses and leguminous species. Furthermore, because Estonia's geographical location and climatic conditions are especially suitable for the growth of perennial grass species (Toomre *et al.*, 1993), the intention is to widen the research into these grasses as basic material for biogas production.

Aims for further research work

- To find out the species and the species mixtures, that could be cultivated in Estonian conditions for biomass production.
- Also to estimate the species energetic values for burning or biogas production.
- To identify the potential species and their mixtures best agrotehnical measures for biomass production.
- To study the mineral elements dynamics in the aboveground phytomass.
- To study the possibilities to manipulate the mineral elements quantities in order to reduce the ash content in the burning process.

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Rohtsete taimede kasutamine bioenergia tootmiseks

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Kokkuvõte

Teiste riikidega võrreldes on rohtsete energiakultuuride alane uurimistöö Eestis alles algusjärgus. Puudub selge ülevaade kultuuridest, mida Eesti tingimustes tasub energia saamiseks kasvatada. Samuti ei ole veel teada, milline tehnoloogia on rohtsetest taimedest energia saamiseks Eestis kõige parem. Soomes ja Rootsis kasutatav energiaheina tootmine ei tarvitse siinsetes klimaatilistes tingimustes ennast õigustada. Probleemiks võib kujuneda kevadine koristusaeg, mis on siin tihti vihmane. Selle tehnoloogia puuduseks on ka suur koristuskadu ja selleks sobivate liikide väike arv. Võimalik, et Eesti tingimustes õigustab ennast paremini biogaasi tootmine, mis energiaheina tootmisega võrreldes ei sea nii rangeid nõudeid substraadi kvaliteedile ning seetõttu saab selleks kasutada enamikku rohtsetest kultuuridest.