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Harvesting of reed canary grass in spring (in May) by precision chopper on cut over peatland.
(Photo: VTT Processes)

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Abstract

In Finland the objective is to utilize reed canary grass and straw on energy production together with other domestic fuels, on filtration of peat production run-off waters and as a raw material of chemical pulp. In Finland the realistic production potential of reed canary grass (abbreviation RCG) and straw on mineral soil is estimated to be 7,9 TWh, which means cultivation of RCG on 170 000 hectares and harvesting of straw on 230 000 hectares.

In Finland some 50 000 hectares of peatlands are utilized on commercial peat production. Of this amount 1000 – 2000 hectares are annually withdrawn from peat production due to gradual exhaustion of the fields. Most of these fields are suitable for cultivation of RCG. RCG plantations can be one method to purify the run-off waters of production areas and landscape production sites.

VTT and Vapo Oy have developed harvesting chains of RCG and straw. The research has included loose harvesting methods operating on mineral soil or on peat production areas and comparative methods based on baling in harvesting of straw. In addition the combustion of RCG and straw has been studied. The existing transportation chains of peat and wood chips can be utilized on production logistics.

1. INTRODUCTION

Potential use of reed canary grass (abbreviation RCG, *Phalaris Arundinaceae*) can be found in energy production, as raw material of chemical pulp and in filtration and evaporation of runoff waters of peat production areas.

Feasible production methods of RCG and straw are based on loose harvesting or baling. The loose harvesting method comprises chopping in harvesting and treatment of loose material in subsequent production phases. In the baling method the straw-like material is baled in harvesting and handled as bales. The advantage of baling is the high density of material, which can reduce transportation costs. The benefits of loose harvesting can be seen in the production of fuel mixtures. Loose matter can be mixed with other similar fuels in any stage of the production chain. Other components of fuel mixtures are peat or wood chips, which are commonly used in Finland.

Straw windrows were combined with a wide ridger to larger windrows
(Photo: VTT Processes)

At active peat production sites, fields are withdrawn from the production gradually. These areas are especially suitable for cultivation of RCG. Without long transportation, the produced biomass can be used for fuel mixtures together with peat. At the same time the reduction of peat energy production can be compensated by increasing the share of RCG. Existing infrastructure, such as roads, machines and buildings, can be used for processing fuel mixtures. In addition the same transportation vehicles of peat and wood chips can be used for the transportation of straw-like biomasses.

2. MATERIALS AND METHODS

VTT has carried out RCG harvesting studies in 1995 – 1997 and straw harvesting studies in 1995 and 1999. RCG research has been done in farming and in bog environments. In 1997, harvesting studies were performed in Hirvineva peat production area near the City of Oulu in Northern Finland. The production site is owned by Vapo Oy Energy, which has founded about 100 hectares of reed canary grass plantations on cutover peatlands near Oulu. These plantations were founded for research purposes in order to study cultivation and to develop energy production and end-use of peat production areas as well as to improve enviromental protection. In addition it has been established growth of RCG in an artificial floodplain for purification research of runoff-waters of peat production. RCG and straw research has been done in fields of Agricultural Research Centre of Finland and in fields of private farmers. Emission and efficiency measurements were carried out in power plants for which boilers were manufactured by Wärtsilä. The power plants used for experiments were equipped with fluidised–bed or mechanical grate boilers.

3. RESULTS

3.1 Cultivation of reed canary grass on peat production areas

In technical sense the cultivation of RCG on peatlands does not differ from that on mineral soils, and normal farming equipment and work phases can be used. The life cycle of RCG plantation is several years. During the two first years, the growth is not harvested. In the first harvesting at Hirvineva cutover peatland in spring 1997, a average potential crop of 7600 kg dry matter per hectare was measured, which is equal to crops on mineral soil. Because the price of artificial fertilisers for RCG production is rather high, alternative fertilisers are also studied. Municipal waste water sludge has been used as fertilisers, and steel plant slag and wood waste boiler ashes have been used as liming subtancies (Puuronen *et al*. 1998)

Figure 1. Reed canary grass in Autumn.
(Photo: VTT Processes)

The cultivation of RCG in peat production areas can help to reduce loading on natural watercourses, as water from the production site could occasionally be drained to RCG plantations. In a research of VTT and Vapo Oy during 1998 – 2000 has been proved that by means of the RCG growth is possible to intensify the purification of peat production runoff-waters on artificial floodplains. Plains have been established in 1998 at cutaway peatland area (Fig. 1). The amount and the quality of inlet and outlet waters during overflows were studied by using automatic flow measuring and sampling units. The crop yield of reed canary grass in late autumn 2000 was quite good, 5800 kg dry matter per hectare. Upkeeping fertilization was not carried out. In 2000 72 – 90 % of solids, nutrient substances and humus load of inlet waters were adsorbed into the reed canary grass plain (Kallio *et al*. 2001)

3.2 Loose harvesting methods of reed canary grass

Three different time points exist for harvesting RCG in Finnish climate conditions. One harvesting time is between August and September, when the growth of the plant has stopped. Harvesting in late autumn, just before the permanent snow cover in November, is in principal possible. The main focus of this study was on spring harvesting, when the snow has melted, but the following growing season has not yet fully started. The advantage of spring harvesting is that the moisture content of the growth is 10 – 20 % and hence, no separate drying stage is needed. In spring or late autumn the nutrients have also returned to roots, which have a favourable effect on fertilisation, ash softening behaviour in combustion and combustion residues. (Pahkala *et.al*. 2000, Flyktman 2000.)

Normal Finnish farming machinery was used in the harvesting tests of RCG. The work stages of harvesting are mowing, chopping and transportation of chopped straw to stockpiles with a forage trailer. Before chopping, windrowing can be done to intensify chopping

The key factor of loose harvesting is chopping, which was carried out with different types of forage choppers. The precision choppers commonly used, also used in this experiment, can only work with cut growth or must be equipped with an optional mowing unit. Some choppers include a moving unit on standard models. Chopping is the slowest stage of harvesting and therefore the capacity of chopping has a significant effect on the economy of harvesting. The other important factor of chopping is the short length of chopped material, which contributes to the density of material during transport, the processing of fuel mixtures and handling on conveyers at power plants.

It was found that windrowing increased the capacity of chopping. Especially the efficient choppers can process the weight of 2 to 3 mowing windrows. Windrowing was carried out with a separate wide windrower or with Front-Pick-Up -unit, which was mounted on front of the tractor, and combined by two mowing windrows. Because of the fragile structure of RCG in spring, some loss is caused by windrowing, especially if roughly handling windrowers are used. The total harvesting losses measured were on average 30%. A typical amount of harvested crop was 5 500 kg dry matter per hectare, which is equal to 25 MWh/hectare.

The demonstration showed that RCG can be harvested with normal farming equipment in the bog environment or on mineral soils. Due to the large total area, the production of RCG can be more efficient on peatlands than on mineral soils on farms. A more efficient and specialised machinery can also be used. Besides the actual production efficiency the transportation of production equipment between small production sites has some effect on the total production costs

Table 1. Working efficiency of five harvesting chains tested in spring harvesting of RCG.

CHOPPER	ELHO	JF-850	JF-900	JF-900	KEMPER
DESCRIPTION	Combined mowing and chopping	Common precision chopper	Precision chopper, Front-Pick-Up -unit	Precision chopper, separate windrowing	Universal precision chopper
WORK EFFICIENCY (hectare/h, working width, m)					
Mowing	-	1.53 2.2 m	2.42 5.1 m	2.42 5.1 m (á 2.8)	2.42 5.1 m (á 2.8)
Windrowing	-	-	-	6.42 6.7 m	6.42 6.7 m
Chopping	0.49 1.7 m	0.54 1.8 m	1.05 *) 3.9 m	1.70 *) 6.7 m	1.27 *) 6.7 m
Transportation	25 m^3	25 m^3	50 m^3	50 m^3	50 m^3
TOTAL TIME, h/hectare	2.25	2.66	1.47	1.26	1.46
ANNUAL PRODUCTION AREA, hectares	51	56	109	163	128
Annual harvesting time 120 h (10 days, 12 hours/day)					

*) after windrowing

3.3 Harvesting methods of straw

On research loose harvesting methods and methods based on baling were tested. On both cases one harvesting chain was based on farm-scale equipment and on the other chain efficient, heavy-duty equipment was used. On loose harvesting two types of precision choppers were used. Baling was done with a round baler or with an efficient rectangular baler. Before the actual harvesting the straw windrows were combined with a separate ridger to larger windrows in order to find out the optimum windrow load for each harvesting machine. The windrowing can increase the harvesting efficiency and lower the harvesting cost, especially with straw, where the crops are small compared to RCG.

Assuming that the straw harvest is 2000 kg_{DS}/hectare, the following work efficiencies were obtained for chopping or baling: the efficient precision chopper 3,9 hectares/h, farm-scale chopper 1,8 hectares/h, round baler 5,0 hectares/h and rectangular baler 10,2 hectares/h. The efficiencies describe the harvesting chain combinations and work methods, for which the total production costs are the lowest.

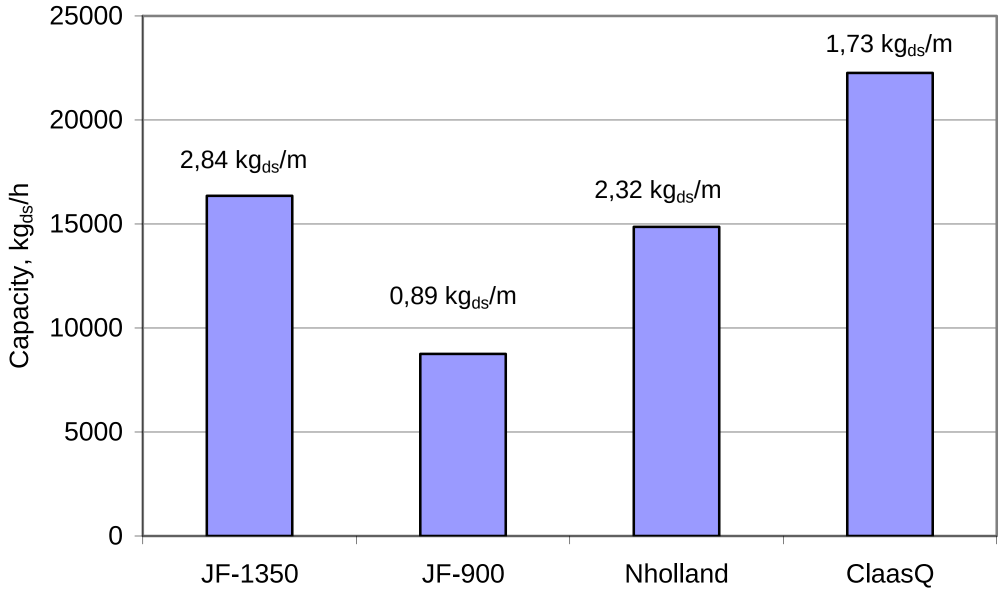

Figure 1. Maximum momentary capacity of choppers (JF-1350 and JF-900) and balers (New Holland and Claas Quadrant) in harvesting of straw and corresponding mass of windrows per meter.

3.4 Storing of reed canary grass and straw

Stockpiles were made of chopped reed canary grass and straw. Pure RCG or pure straw was used or RCG was mixed with milled peat or sod peat. In terms of energy content, the share of RCG in mixed stockpiles was 10%, which by volume is equal to 40% with sod peat and 30% with milled peat. All stockpiles were coated with plastic cover, which is used in peat production.

If the moisture content was less than 20 – 24%, RCG or straw preserved well on stockpiles (Lindh *et.al*, 2000). No significant temperature rise or quality decrease was observed. The sufficient moisture content of RCG is achieved in spring harvesting without a separate drying stage.

In mixed stockpiles RCG absorbed some moisture from peat. The initial moisture contents of milled and sod peat were 48% and 29%, respectively. In mixed stockpiles, the temperature rose up to 40 - 50 °C, which is typical on peat stockpiles. The quality of RCG did not change significantly anyway, if the increase in the moisture content of RCG is not considered.

3.5 Transport of reed canary grass and straw

In Finland the existing transport equipment of peat can be used on transport. Due to low density of hay like fuels, the loads on long distance transport are smaller than those of peat or wood chips. Therefore also the economical transport distances are shorter. The load of loose matter in a truck is typically 7000 kg_{ds}. The mass of round bale load is about 10 000 kg_{ds} and the load of large rectangular bales is about 14 000 kg_{ds}. The benefit of large bales is that timber truck can be used on transport, so the separate loader is not needed.

3.6 Economy of production reed canary grass and straw

The production costs of reed canary grass can be divided into five cost factors: foundation of the growth, annual fertilisation, harvesting and storage, long-distance haulage to users and productive value of the field. The cost of each production stage consists of investments made in machinery and work costs. When machines are used also in agriculture, the machine investments can be divided between normal farming and production of straw-like fuels.

According to harvesting tests, the total production costs are about 15 €/MWh (Lindh *et al*. 2000). If the productive value of the field is excluded, the production costs total to 10 €/MWh. The share of actual harvesting costs is about 3.4 €/MWh, and with long distance haulage about 5.9 €/MWh at a distance of 30 km. The delivery price of peat is about 8.4 €/MWh.

The division of production costs into production stages is on average: foundation of growth 10%, annual fertilisation 19%, harvesting 26%, long distance haulage 15% and productive value of land 31%. The largest individual cost items are productive value of land (30% of total production cost), annual fertilisation (15%), long distance haulage (15% to 30 km), chopping of RDG (10%) and seed and fertilisation on foundation (6%).

Straw harvesting costs were calculated. The harvesting was based on loose matter or bales. In addition farm-scale equipment or heavy-duty equipment was studied. For these harvesting chains the calculated total production costs were 6.3€/MWh (heavy-duty precision chopper), 7.1 €/MWh (farm-scale precision chopper), 6.4 €/MWh (round bales) and 5.7 €/MWh (heavy-duty rectangular baler) including the transportation to power plant with distance of 30 kilometres. The baling methods do not include the cost of separate chopping of bales, which is calculated to be about 3.9€/MWh, if a round bale chopper is used. If chopping of bales is carried out on this manner, the baling methods are not competitive with loose harvesting methods. If chopping of straw is done on baling, and the quality of chopped straw is satisfactory for fuel use, the costs of rectangular baler harvesting chain are little lower compared to corresponding loose harvesting chain.

There are no significant difference between the production costs of loose harvesting and baling methods. The balers commonly employed are not equipped with a chopping unit, and hence, shredding and chopping of bales must be carried out, for example, on a power plant. The benefit of the high density of bales is partially lost, if round bales, common in Finland, are used.

3.6 Combustion of reed canary grass and straw

Ash softening behaviour is the most important factor in availability of RCG and straw for combustion. The ash softening temperature of spring-harvested RCG is higher (1 125 °C) than that of autumn-harvested RCG (820 °C). Potassium and sodium residues are much smaller for spring-harvested RCG. Therefore, the fuel properties of the spring harvest of RCG are superior to those of the autumn harvest. The ash softening temperature of straw depends on cereals e.g. for wheat the temperature is more than 1050 ^{o}C and for oat only about 800 ^{o}C.

In combustion experiments, RCG or straw was mixed with wood chips, wood waste and sod or milled peat. A typical energy portion of RCG or straw in the mixture was 5 - 15% (15 - 40% of the total volume). The power plants used for experiments are equipped with fluidised-bed or mechanical grate boilers, which are common in Finland. The measurements showed no emission increments from mixed fuels compared with a normal fuel, when spring-harvested RCG or straw was used (Flyktman 2000). The combustion equipment operated almost without disturbances. Some technical problems appeared in fuel-handling systems, for example, in conveyors and surface level detectors. To avoid disturbances, the size of RCG and straw chaff should be short and the mixing should be thorough, so that no large clumps of pure RCG or straw get into the handling system.

4. CONCLUSIONS

Due to low energy content RCG and straw are only supplement fuels: the typical energy share is 10 % on a fuel mixture. At present the use of RCG and straw as fuel is marginal, but is increasing. The harvesting chains are based on existing farming equipment. The combustion of RCG and straw can be managed. The relatively high production costs compared to peat or coal can limit the use of RCG and straw. The competitiveness is better if compared to wood chips.

5. ACKNOWLEDGEMENTS

The study is mainly funded by Tekes (Technology Development Centre of Finland), Vapo Oy Energy and VTT. Vapo Oy also provided the peat production areas for harvesting tests. The combustion study is mainly funded by Tekes, Wärtsilä and VTT. Other co-operation partners were Agricultural Research Centre of Finland, which provided fields for harvesting tests of reed canary grass and straw, and Regional Development Centre of South-West Finland (Loimaa).

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