ENERGY WILLOW FARMING ON OLD PEAT INDUSTRY AREAS.

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SUMMARY

Fast growing energy willows for short rotation forestry have been studied in Finland and in Sweden since 1973. The energy yields in the trials have been promising, up to 350 GJ/ha annually (up to 20 tn/ha DM). The main lines of the energy willow farming have been established, and large scale experiments on old peat industry areas have been started. The bottom peat layer still left on these areas has been found to be an exceptionally sterile growing environment: there are no weeds, no diseases, no insects present. The bottom peat is, however, rich in calcium and especially in nitrogen. The energy willow husbandry on the old peat industry areas aims at mobilzing these natural nitrogen reserves. This can be done with the willow ash fertilization. The nitrogen mobilization is a by-product of an increased activity of bacteria which takes place after ash application. However, some mineral nitrogen is still needed for the early summer growth when the activity of bacteria is low. Even with energy demanding mineral nitrogen use, the energy willow farming shows a high positive net energy gain and calls for intensified research.

INTRODUCTION

Energy farming is a discipline of cultivated plants and husbandry in which the solar radiation is collected and converted into biotic energy of the phytomass. The aim is to produce high energy yields by selecting, breeding and raising fast growing crops (1).

Promising results in northern energy farming have been achieved with the use of selected willow clones. Energy willow farming was developed in Finland and in Sweden in the mid-seventies. It has its modern origin in the concept of mini-rotation forestry (2). Initially the aim was merely to produce more raw material for the expanding wood industry, using methods as intensive as those used in agriculture.

The first field experiments were established in 1973. Promising results were obtained at once. A Danish willow clone, Salix cv. "Aquatica" produced in the latitude of the arctic circle a dry matter (DM) yield of about 10 tons/ha already during the first summer (3).

More willow species have been screened in subsequent experiments. The annual yields have been maintained at their high level, between 10 and 20 tons/ha, in energy equivalents up to 350 gigajoules (GJ) per hectare (4). The largest dry matter yield so far reported (5) has been 32 tons/ha, which includes the harvested stemwood only.

ASPECTS OF WILLOW FARMING

Energy willow farming can be carried out in two ways. If the clones used are completely frost resistant they can be grown like any other deciduous crop; the rotation time will vary between 2-5 years. If the shoots do not survive the winter, but the stumps and roots do, a one year rotation period is used.

So far it is not yet clear which one of the two practices will give the highest yields. With a rotation period of a number of years, dormancy reduces the level of photosynthesis in the autumn, but in early summer the foliage develops rapidly on the already existing shoots. With one year rotation the growth early in the growing season is slower. However, as there is no need for winterhardening of the shoots, the leaves continue to fix carbon at a high rate right up until the onset of the autumn frosts. The active period of willow under one year rotation lasts until October. The period is about one month longer than that for birch.

In the central and southern parts of the Nordic countries 2-3 year rotation will probably give the highest yields. Moreover, perennial crops seem to produce more energy-rich shoots that also are structurally better suited to the cutting devices of future harvesting machines (6).

One advantage of energy willow is that it can be clonally propagated. The crop is established using cuttings. After the first harvest the willow will coppice 5-20 shoots per cutting, depending on genetic differences between the clones.

The shoot density, which is greatly determined by the coppicing ability, has a clear effect on the yield. The main rule holds that the larger the number of vigorous shoots, the greater the yield will be (7). As a practical compromise, we aim at a shoot number of 30 per square meter in one year crops. With this density full coverage is established within 30 days in the spring.

Row cultivation can be carried out in such a way that ordinary tractors can later on operate without damaging the stools. Planting as well as harvesting can be mechanized at little cost.

GROWTH POTENTIAL OF OLD PEAT INDUSTRY AREAS

By the end of this century the expanding peat industry, for instance in Finland releases a soil surface area of approximately 50,000 hectares, an area where the peat mining is over and the problem of further utilization of these areas sould be solved.

When the last peat mining machine rolls away from the peat industry area, it leaves a moderately drained, even bottom peat soil behind. Due to the irregular mineral soil profile beneath the peat, and due to the present peat mining method, the depth of the bottom peat is still 30-50 centimeters. What is the growth potential of this kind of bottom soil?

As compared to other cultivated soils, the old bottom peat has a remarkable advantage. As a growing environment it is exceptionally sterile: there are no weeds, no diseases, no insects present. This advantage should be utilized without delay, for the annual weeds distributed by the wind, will find the bare soil surface in a couple of years after the peat mining.

However, the bottom peat is fertile. Already when studying the natural peatlands, it has been found out that the calcium and nitrogen content of the peat are increasing from the surface peat towards the bottom peat. The acidity, for instance, may change from 3.5 (surface) to 5.5 (bottom) pH-units. At the same time the nitrogen content in the peat dry matter goes up to two percent.

As regarding phosphorus, potassium and other mineral nutrients, the bottom peat is a poor environment. However, due to the neighbourhood of the mineral soil beneath, the plants with a deep root network may utilize the nutrients concentrated in the mineral soil.

As a growing media for different cultivated plants, the old peat industry area is an excellent one. The peat mining is a superior method over the conventional methods, when clearing peatlands for cultivation purposes. Although these areas are suitable for almost any cultivated plant, it seems logical and natural to continue energy production, now through energy farming.

ENERGY CROP FERTILIZATION FOR BOTTOM PEAT

If the energy crop is burned in a heating plant, most of the nutrients can be returned to the plantation in the ash. In actual fact, nitrogen is the only remarkable nutrient that vanishes (to the atmosphere). The energy willow ash is an excellent fertilizer for energy willow growing. It contains the mineral nutrients needed (except nitrogen) just in correct relationships.

The need for the annual ash return and nitrogen fertilization can be calculated from the corresponding ash and nitrogen content of the energy willow yield. Let us use as a practical example of *Salix* cv. "Aquatica" cultivation with a moderate stem yield of 12 tons/ha/year (DM), or 197 GJ in energy terms (4). The rotation cycle is one year, and the leaves which contain a considerable amount of mineral nutrients fall annually to the ground as litter.

The ash and nitrogen content of the stems of energy willow are 2.5 and 0.75 percent, respectively. Thus the removals are 300 kg/ha for ash and 90 kg/ha for nitrogen. These amounts at least should be returned to the willow plantation annually in order to maintain the nutrient balance.

Nitrogen fertilizer is fixed from atmospheric reserves using a certain amount of energy. It has been estimated that the whole nitrogen chain from the atmosphere through the factory to the field, requires an energy input of 77.0 MJ/kg nitrogen as fertilizer (8). Nitrogen fertilization at a dosage of 90 kg/ha will thus require an energy input of 6.9 GJ. Therefore a part, in this case 3.5 percent, of the gross energy yield must be reserved in order to maintain the cycling of nitrogen between the atmosphere and the energy plantation.

Annual nitrogen fertilization at this level may seem somewhat high. If a suitable peatland is selected for energy willow cultivation, the nitrogen dose can be reduced. In a cultivation layer 30-50 cm thick, there are those nitrogen reserves, actually for 100 years' energy farming if reliable means of mobilizing the nitrogen were found.

Ash fertilization also plays a central role in the nitrogen mobilization. It has been found in Finnish peatland fertilization experiments that the activity of bacteria, especially that of ammonifying bacteria increases dramatically after ash fertilization. As a result, the nitrogen mobilization is speeded up, and the level of nitrogen fertilization can be reduced. However, some mineral nitrogen is needed as a booster for the early summer growth, when the temperature is too low to maintain a high level of bacterial activity.

Nitrogen fertilization represents the biggest single energy input in the willow husbandry. However, even if all the nitrogen requirements were satisfied with energy demanding mineral fertilization, this activity shows a high net energy return: 20-30 times the energy put into the system can be harvested in the gross willow yield.

ROLE OF PEATLANDS IN ENERGY FARMING

In a global scale, the energy farming cannot compete with food production about the land areas. Therefore the possibilities must be sought in areas other than the cereal crop growing zones. Owing to the geographical distribution of the land area the main part of the world's energy farming area could be found in the northern hemisphere, if suitable crop husbandry were found. Here, the low level of evapotranspiration results in a excess of water over a large zone, although the annual rainfall is usually below 1000 mm.

The northern peatlands can be regarded as one of the most remarkable reserve areas in the world awaiting clearance for cultivation purposes. The peat industry has shown that with present machinery efficient drainage of peatlands can be easily carried out and the excess of water is no longer problem.

The total area of peatlands in the world has been estimated to be at least 230 million hectares (9). Part of it lies in the tundra zone, but if every other hectare could be utilized for energy farming, the area would still equal, for instance, the present agricultural area of the U.S. With the moderate energy yield level (197 GJ/ha) of our example, this area alone would total about 20 exajoules. It is of the same magnitude than the present annual energy demand of for instance U.K. or West Germany (10).

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