Environment-friendly and energetically efficient cultivation of energy plants on sandy soil

V. Scholz*[a], R. Ellerbrock[b]
[a]Institut für Agrartechnik Bornim, Max-Eyth-Allee 100, D-14469 Potsdam, Germany
Fax: +49-331-5699-849; vscholz@atb-potsdam.de
[b]Zentrum für Agrarlandschafts- und Landnutzungsforschung Müncheberg, Germany

Energy plants, cultivated on set-aside land, could substitute nearly 3 % of the primary energy in Germany and could raise the income of farmers. However, the substitution of fossil fuels by plants requires the selection of plant species with high site suitability, an ecologically benign farming system and high yields. If these requirements are satisfied, a durable economic and ecological advantage, as well as the acceptance by politics and the public can be expected.

Method and Material

A field trial site was established as a split-plot on sandy soil (Sl, Albic Luvisol) in Potsdam-Bornim in 1994. On 3 hectares of land ten different annual and perennial energy plants intended for combustion were tested under comparable soil and climate conditions (540 mm/a; 9,4 °C). Objects of the evaluation were plant species such as cocksfoot grass, poplar, willow, Jerusalem artichoke and hemp, as well as energy cereals such as triticale, winter rye and perennial rye. The yearly nitrogen-fertilisation was carried out at three intensity levels from 0 up to 150 kg N/ha for each crop. For base fertilising conventional mineral fertilisers were used, as well as straw and wood ash. Pesticides have not been applied so far.
The measuring programme includes the evaluation of yields and ecologically relevant plant and soil contents, as well as nutrient circulation and accompanying faunistic studies [1].

Yield

The 6-years-average of the dry matter yield of the tested energy plants ranges between 3.3 t/(ha·a) (Jerusalem artichoke) and 11.8 t/(ha·a) (hemp). The yield of the stalks of Jerusalem artichoke drops rapidly after the first year, independently of the harvest of potatoes. Cocksfoot grass (2 to 3 harvests) and energy cereals render yields of up to 9.4 t/(ha·a); poplar without under seed up to 10.2 t/(ha·a). Missing herbicides do usually not cause a significant yield decline of annual crops, because all plants, incl weeds, are havested [2].
Reduced N-fertilisation leads to an average yield loss of 6 % and non-fertilisation to a 20 % to 40 % loss after 6 years. However, the yield of poplar shows no dependence of the application of nitrogen. This short rotation coppice does obviously not need any fertiliser, at least during its first 5 to 10 years of growth [3], but there is a substantial dependence on the variety and the established under seed (grass). The grass is a considerable nutrient and water competitor, which causes a yield loss of about one third and which has no significant influence on the faunistic biodiversity, e.g. on the number and variety of arthropods. In contrast to willow, poplar suppresses the grass after 4 to 6 years.

Ecologically harmful substances

The content of emissions-relevant substances in the investigated plants varies in a very wide range, e.g. nitrogen from 0.3 to 2.4 %, potassium from 0.2 to 1.9 %, sulphur from 0.04 to 0.33 % and chlorine from 0.01 to 0.16 %. In poplar and willow the concentration of these substances is significantly lower than in cereal and hemp. Cocksfoot grass has the highest one of all. Only rye has a similarly high concentration of chlorine, which is responsible for the very toxic dioxin.
The nitrogen content shows a dependence on the fertilisation level. An application rate of 150 kg N/ha results in an absolute increase of the nitrogen content of plants by 0,1 to 0,3 % and thus in a considerable rise of NO_x-emissions during combustion of these plants [4].
Heavy metals accumulated from fertilisers and energetically generated pollutants such as cadmium, lead, copper and zinc are absorbed to a different degree. Trees preferably assimilate cadmium and cereals copper. In contrast to rye and triticale, the balance of cadmium is negative for poplar and willow, i. e. these plants are able to decontaminate the soil and purify the nutrient cycle by extracting this heavy metal

and concentrating it in the filter ash during combustion, even if the grate ash is used as a fertiliser on the same field.

Energy gain

The energy balance depends in particular on the yield and the amount of fertiliser and shows a net gain (output – input) of more than 130 GJ/(ha·a) for well-fertilised hemp and non-fertilised poplar. Energy cereals and grass reach 90 to 120 GJ/(ha·a). The reduction of nitrogenous fertiliser from 150 to 75 kg N/ha does not usually lead to a loss of energy [5] (Fig.1).

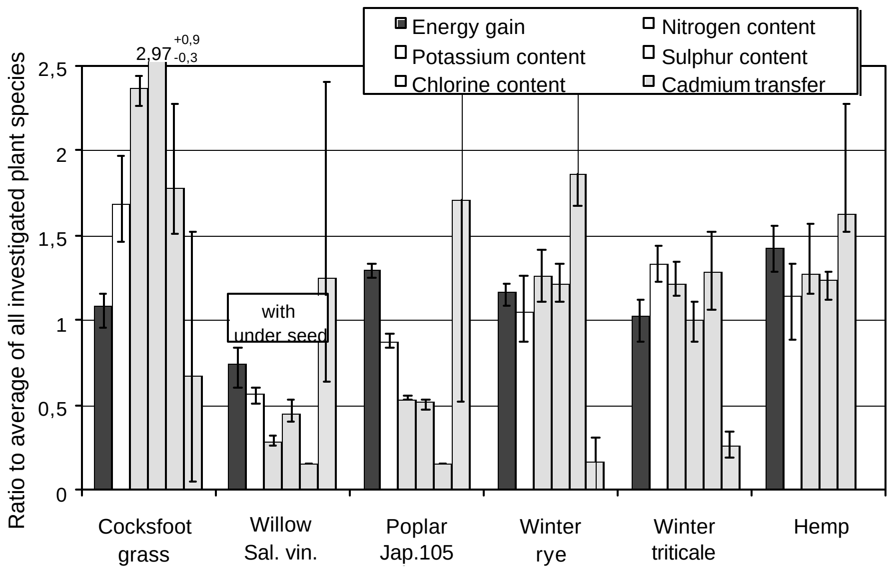

Figure 1: Comparison of energetically and environmentally relevant parameters of selected energy plants

Conclusions

The results of this 6-year field trial confirm the possibility of the ecological production of energy plants on sandy soil. In general no pesticides are necessary. Fertiliser application can be reduced to a certain degree without losing any energy gain. This gain is enough to supply two families households with heat throughout the year. Some plant species, especially poplar and willow, have a minimum of emissions-relevant substances such as nitrogen, sulphur, potassium and chlorine. The same species have the ability to accumulate heavy metals, especially cadmium, which may be helpful for the decontamination of the soil, even if the grate ash is brought back to the field.

Poplar and willow are to be favoured not only regarding environmental and energetic aspects, but also others such as harvest time in winter, a harvest interval from 2 to 10 years and especially the wooden properties of the fuel, which makes it appropriate for conventional wood boilers.

References

[1] Scholz V et al. Umwelt- und technologiegerechter Anbau von Energiepflanzen. Research report of the Institute of Aricultural Engineering Bornim 1999/1, Potsdam 1999, 137 p.

[2] Karpenstein-Machan M. Auswirkungen von pestizidfreiem Energiepflanzenanbau auf die Biomasseerträge. energie pflanzen II/2000, p. 32-35

[3] Hofmann M. Modellvorhaben Schnellwachsende Baumarten. Schriftenreihe Nachwachsende Rohstoffe, Band 13, Münster1999, 476 p.

[4] Nussbaumer T. Primär- und Sekundärmaßnahmen zur NO_x-Minderung bei Biomasse-feuerungen. VDI-Bericht 1319, 1997, p.141-166

[5] Scholz V. Energy balance of solid biofuels. J. agric. Engng Res. (1998) 71, p. 263-272