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Environmentally friendly and energy efficient energy crop production

Energy plants could soon be a permanent part of fuel mixes in Germany. A requirement for this, however, is that the plant types used, their cultivation and exploitation, can be tolerated by the environment and yield enough energy to justify the effort involved. Practice-oriented growing trials carried out over six years with ten types of energy plant under various manuring regimes indicate that tree crops (poplar, willow) contain substantially less environment-damaging material than do cocksfoot, rye, hemp and triticale and that they also play a role in reducing heavy metal pollution of the soil.

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Energy crops not only play a role in the reduction of greenhouse gas emissions but also offer help in the stabilising of farmer incomes. These plants, grown on land preferably not required for food production, could, in the medium term, deliver something like a third of the energy produced from biomass and even with that manage to supply 3% of Germany's primary energy requirement. Although we are here discussing regenerative energy fuels, the plants involved have in the long-term only a chance when their cultivation and exploitation lead to no unacceptable environmental damage and where their net energy yield per area unit is sufficiently high.

Methods

The trial area within the ATB fields was divided into ten long plots each of 0.25 ha with each of these divided into four 624 m^2 plots (see diagram p. 123). Block A received a basic mineral manuring and 150 kg N/ha. Blocks B and C received an application of ash from timber and straw as well as 75 kg N/ha in each case and block D was not manured. Plant protection substances were not applied. Only plants suitable for burning or gas-production were grown whereby the focus was on perennials. Upper topsoil comprised a sand low in humus and loam over sandy loam (ground points = 30). In the trial period 1994 to 1999 the average year temperature was 9.3 ± 1.8 °C and precipitation total 523 ± 184 mm/a [1].

Yields

On the highly-fertiliser areas (block A) the highest wholecrop yields were achieved by hemp with 11.8 t_{DM}/ha, winter rye, cocksfoot and winter triticale with 8.5 to 9.4 t_{DM}/ha. The lowest yields were achieved with the originally very promising topinambur (*fig. 1*).

Compared to the results from the Nr. application of 150 kg/ha (block A), the yields from the 75 kg N/ha treatment blocks B and C were reduced by only 6% over the six year trial period and indicated no time-associated tendency. A policy of absolutely no manuring (block D) resulted in a yield reduction of around 20 – 40% in the sixth year. The yields of short rotation coppice (tree) crops were exceptional in their range, being influenced less by the amount of fertiliser applied and much more by the plants growing under the crop and age of crop. Undersown crops, being substantial competitors for water and nutrition, led to average yield penalties of from 10 to 65%. Apart from the non-representative poplar variety Nr. 42 which showed an extremely high mortality rate, the yield penalty for poplars without grass undercropping and with no manuring (block D) was only 1% to 6%, depending on rotation interval, compared with full manuring (block A) [2, 3].

Environment-relevant nutrients

The nitrogen content (N_t) of the various types of plant showed an extraordinary range. With 0.8 to 1.7%, cocksfoot, cereals and hemp achieved the highest average N_t content. The content of the coppice and topinambur, at 0.3 to 0.8%, was substantially lower. The results of the investigations permitted a correlation – confirmed by regression analysis – between manuring and plant nitrogen content. A nitrogen application of 150 kg/ha caused, according to this and depending on the type of plant, an average absolute increase in N_t content of from 0.1 to 0.3%.

With regard to the experimentally-confirmed associations between the nitrogen content of the fuels and the production of NO_x during burning [4, 5], an application of 150 kg nitrogen as a rough average therefore leads to around 50 mg/m^3 additional NO_x emissions which, with a legal threshold of 400 mg/m^3, is not an inconsiderable amount [6]. As gas measurements on the trial areas over many years have indicated, the 150 kg N/ha nitrogen manuring results in an annual release from the soil of up to 100 mg/m^3 additional nitrous oxide N_2O [7], which represents up to 20% of the total emissions that can be calculated of climate-affecting gases from cultivation and exploitation of solid fuels from harvested vegetation [8].

The potassium (K) content of cocksfoot, wholecrop cereals and hemp was > 0.85%, for poplars and willows, on the other hand, >0.45%. High K content leads, through bur-

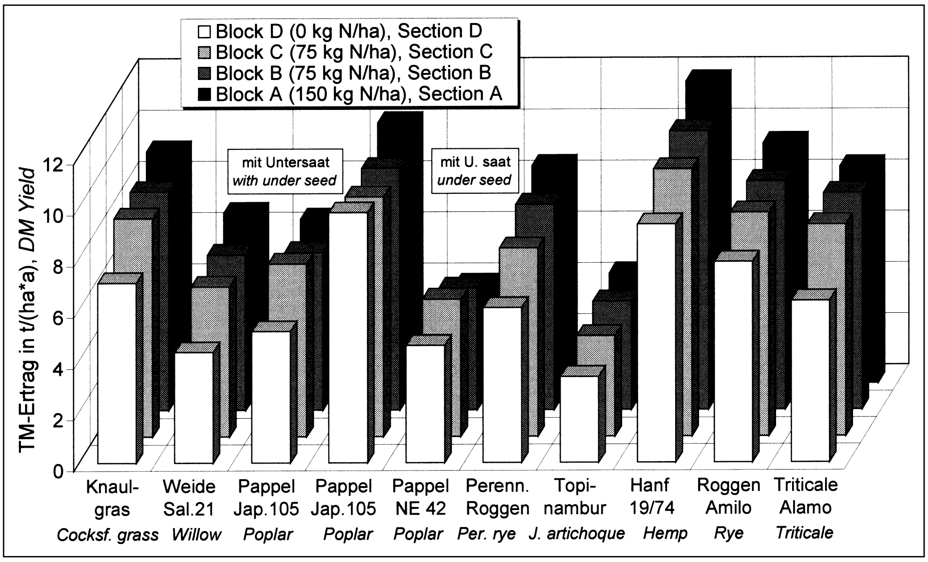


Fig. 1: Several years` median yield of the energy crops investigated (1994 to 1999)

ning, to an increase in corrosion and slag production and is therefore not desirable. As with nitrogen, an association was also apparent here between K content in the plant and in the soil.

The contents of the two micronutrients sulphur (S) and chlorine (Cl) which are especially important emissions leading, in part, to highly toxic compounds lie, with the exception of cocksfoot, in the range cited by the literature [9 to 14]. The types of winter cereal and of hemp showed, with 0.10 to 0.14% S and 0.08 to 0.16% Cl, substantially higher contents than the coppice crops (≤ 0.08% S and ≤ 0.01% Cl). The sulphur content of the plants is also apparently dependent on the manuring. In the case of chlorine, however, no definite dependency was able to be determined (*fig. 2*).

Heavy metals

Of the heavy metals analysed in the soil and plant material, the ones of interest here are above all those whose accumulation, caused through energy-associated pollution and/or through inclusion in fertilisers, namely cadmium, lead, copper and zinc, whereas the first is especially problematic. This heavy metal, which occurs through burning and is present in superphosphate and partly also in biomass ash, is phytotoxic and can lead to serious health problems. With average contents of 1.2 to 2.2 mg per kg dry matter, cadmium (Cd) is absorbed with preference by poplar and willow. Wholecrop cereals such as rye and triticale show substantially smaller contents with 0.03 and 0.08 mg/kg_{DM}.

Energy yield

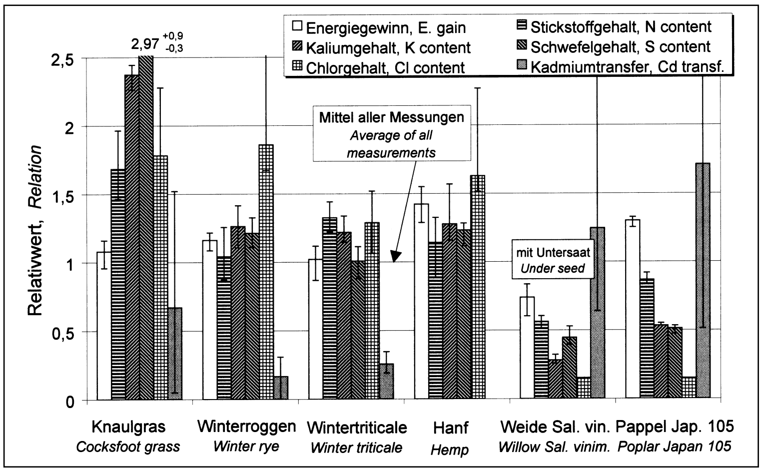
In order to determine the energy surplus, effort and yield have to be calculated in energy terms and then compared. The determination of accumulated energy input is through a complicated method which has already been explained and which, e.g., also takes account of the energy requirements in the manufacture of tractors and fertilisers [15, 16]. For growing and harvesting the investigated plants this was equal to 2 to 14 GJ/(ha•a) according to type of plant, harvesting interval, technology and fertiliser application.

The energy yield in particular is dependent on type of plant, undercrop and fertilising. If the extremely low yielding trial components such as topinambur and undersown coppicing are taken out, this yield lies in the region of from 90 to 170 GJ/(ha•a).

The annual (net) surplus energy production taken from the difference between the effort input and yield lay between 88 and 158 GJ/(ha•a) with hemp, poplar (without undercrop), cocksfoot and cereals for all fertiliser application variants.

Bild 2: Vergleich energetisch und ökologisch relevanter Parameter von ausgewählten Energiepflanzen

Fig. 2: Comparing energetically and ecologically relevant parameters for selected energy crops



Summary

The trials indicated that fertiliser applications can be substantially reduced, and plant protection materials mostly done without, when growing energy crop plants on sandy soil. Yield was only slightly reduced by reducing the nitrogen application from 150 to 75 kg N/ha. Without manuring, the yield dropped continually and after six years reached around 60 to 80% of the respective yields from 150 kg N/ha applications. An exception here was the poplar Japan 105 without undercrop which also delivered high yields without nitrogen application.

A nitrogen application of 150 kg /ha is energy inefficient. Sustainable high yields of surplus energy were also realised with applications of ≤ 75 kg N/ha. With the exception of topinambur and undersown coppicing, the net energy yield under reduced nitrogen fertiliser input lay in the range from 2800 to 4200 litres of oil-equivalent per hectare and year.

With contents of ≤ 0.8% N, ≤ 0.4% K, ≤ 0.08% S and ≤ 0.01% Cl the copping plants poplars and willows belong to the energy plants that cause the lowest level of emissions on burning and show an extraordinarily high heavy metal accumulation potential, especially for cadmium. Because of the concentration of the heavy metals in the filter ash, a sustainable role towards decontamination of the soil can be played, even where the soot ash is returned to the land as fertiliser. Further advantages of short rotation coppicing include the harvest in winter, the harvest interval which can be freely chosen between two and ten years, and the possibility of subsidised growing on set-aside land. The decisive advantage is, however, that these crops produce a fuel for which tested and proved emission-minimising burning technologies are already available.