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The role of black locust (*Robinia pseudoacacia* L.) in establishment of short-rotation energy plantations in Hungary

Rédei, K. & Veperdi, I.

Forest Research Institute, H-1023 Budapest, Hungary
E-mail address: redei.karoly@t-online.hu, veperdii@erti.hu

Summary: Establishment of short-rotation energy plantations for fuel production has been of international interest for many years. Energy plantation experiments in Hungary have been conducted for a longer time. In the country black locust (*Robinia pseudoacacia* L.) is one of the most important stand-forming tree species, covering approximately 23% of the forested land (410 000 ha) and providing about 19% of the annual timber output of the country. This fast growing species seems to be suitable for energy plantations as well. So, in Helvécia (Central-Hungary, sand-soil region) two energy plantations were established using common black locust and its cultivars improved in Hungary. The spacing variations of the common black locust were: 1.5×0.3 m, 1.5×0.5 m and 1.5×1.0 m. At the age of 5 the closest spacing (1.5×0.3m) produced the greatest annual increment in oven-dry weight (6.5 t ha^{-1} yr^{-1}). In the trial with black locust cultivars planted in spacing of 1.5×1.0 m, at the age of 7 the highest annual increment in oven-dry mass was produced by the cultivar '*Üllői*' (9.7 t ha^{-1} yr^{-1}) followed by the common black locust (8.4 t ha^{-1} yr^{-1}) and the cultivar '*Jászkiséri* (7.6 t ha^{-1} yr^{-1}). The trials have verified that in temperate climate the increment in oven-dry dendromass of black locust energy plantations has ranged from 6 to 12 t ha^{-1} yr^{-1}. On the basis of the trials' evaluation the quantity of dendromass mostly depends on site quality, species and cultivars, as well as on the initial spacing (plants per hectare).

Key words: Black locust (*Robinia pseudoacacia* L.), energy plantations

Introduction

The energy crisis of the early 1970's stimulated renewed interest in short-rotation crops (plantations) in temperate countries. Planted crops which are subsequently coppiced on 4 to 5-year cycles are economically valued as alternative sources of wood, charcoal, and liquid fuels, a basis for chemical processes, wood pulp, and sometimes as a folder supplement. Forest crops (plantations), of course, are not the only sources of biomass for energy, though they are among the most efficient in terms of the rations of energy contained in the harvested crop to total energy input.

In Hungary the harvested annual wood is about 7 million cubic meters. The demand for timber is high. It is used by building industry, furniture industry and packaging and paper industries. About three million cubic meters of wood is used each year for energy fuel. Approximately 0.5 million cubic meters of used-wood products is annually consumed to produce heat energy for industry or directly marketed for the population.

Considering the total wood-consumption, 55 per cent is utilized for producing energy and 45 per cent is used as industrial raw material. Only about 70 per cent of the country's demand for timber can be met from current forests production. According to the EU regulations the ratio of the renewable energy sources should be increased by 20 per cent till 2020. In Hungary this value would be 13 per cent. The plantations established for producing biomass (dendromass) and managed on a short rotation in general, may contribute to meet the demand of wood for energy purposes as a renewable source.

The major advantages of establishing energy plantation are:

- They are renewable (continuous) and reproduce systematically.
- They provide an alternative for utilizing lands on which agricultural production is abandoned temporarily.
- They are environmentally compatible (protect against erosion and defoliation) if good growing technology is applied.
- They decrease the use of fossil energy sources, which pollute the environment with sulphur and ash.
- The ash of burnt wood can be used as nutrient for supplemental fertilizers.
- By establishing energy plantations on a large scale, the cost of geological research in connection with mining and mine openings can be reduced.
- They can be distributed in the country more uniformly than the fossil energy sources.
- Capital for establishment is considerable less and the length of time for a return on the investment is shorter than that of the fossils energy sources, especially compared to deep underground coal-mining.

- Their wood material can be used at most any time, and plantations can be established near the area of consumption, thus reducing the transportation cost.
- They could contribute to the employment of people in the given area.

In Hungary the purpose of establishing experimental energy plantations is to determine the species and cultivars which produce the highest yield on the available sites, and to develop the most productive and profitable technologies. On the basis of the results achieved by the experiments, we are able to answer many questions on growing energy plantations. We know more about which site, and which growing technology should be used for energy plantations.

The role of black locust in establishing energy plantations

In Hungary, the black locust occupied 37.000 ha in 1885, 109.000 ha in 1911, 186.000 ha in 1938 and 410.000 ha in 2007. This is approximately 23% of all forested land in Hungary. One-third of black locust stands are high forests, while two-thirds of them are of coppice origin. In the 1960s, Hungary had more black locust forests than all the other European countries (*Rédei,* 2003).

Black locust timber can be used by industry (mining, construction, furniture) or by agriculture (post and pole wood), and black locust stands are the main basis for Hungarian apiculture and honey production. The black locust is one of the most suitable tree species for establishing energy plantations and for transforming existing traditional forests into energy forests.

The frequently expressed misconception that rapid growth rate is associated with low wood density is clearly disproved by black locust. Not only has the species a very high density, 690 kg/m^3 and more, but it has a very rapid height growth rate, 2–6 cm/day, which places it among the most rapidly growing plants in its juvenile stage. With this combination of both high density and volume increment black locust can achieve impressive dendromass yield over various rotation ages when grown on good sites. Moreorver, because of its ability to fix atmospheric nitrogen, it requires little or no nitrogen fertilization. Considering these growth criteria (volume and density) and the symbiotic associations of both bacteria and mycorrhizal fungi, black locust offers an excellent experimental organism for basic studies on growth control in woody plants, as well.

More and more agricultural land is being taken out of use for food crops, some of which can be used for energy production plantations. Black locust is one of the best tree species for this purpose, thanks to its some excellent energy production properties, such as:

- vigorous growing potential in juvenile phase,
- excellent coppicing ability,
- high density of the wood,
- high dry matter production,
- favourable combustibility of the wood,
- relatively fast drying,
- easy harvesting and wood processing.

Materials and methods

In the last decade several energy production plantations have been established in Hungary. In these experiments different spacing treatments were tested and the common black locust as well as its cultivars were compared.

In an energy plantation trial with common black locust at the subcompartment Helvécia 80A (Central-Hungary, Danube-Tisza Interfluves) on slightly humous sandy soil without ground-water influence, three spacing variations – 1.5×0.3 m, 1.5×0.5 m and 1.5×1.0 m – were used in three replications.

In the same subcompartment we set up a black locust cultivar trial, too. The following cultivars improved in Hungary were used in a spacing of 1.5×1.0 m: *'Üllői'*, *'Jászkiséri'*, *'Nyírségi'*, *'Kiscsalai'* and common black locust (control). The planting material was one-year-old rooted cutting (in case of cultivars) and one-year-old seedling (in case of common black locust).

In each trial plot, the dbh ($d_{1.3}$) and height (h) of 50 marked trees at the age of 5 and 7 years were measured. The mean tree by volume (v) was computed as a function of $d_{1.3}$ and h from a yield table (Sopp, 1974). Volume (V/ha) = v x N, where N was computed by spacing variations. The total above-ground dendromass was determined for the mean tree by volume measurements by sections. The green dendromass was calculated for the whole tree (including branches and leaves), while the oven-dry dendromass was determined only for the stem in lab. The trial at Helvécia is not on the very best site. The annual precipitation amounted to only 500 mm in some years, while in the dry summer period it was less than 300 mm, meaning that water supply was the minimum factor influencing the dendromass production. Thus, yield results are more characteristic for the quality of site than for the potential productivity of the particular tree species.

Results

The results of the common black locust spacing trial can be found in *Table 1.*

Table 1. Evaluation of the common black locust spacing trial for energy production (Helvécia 80A)

Factors		Mean		Oven-dry dendromass t ha^{-1}	Increment of oven-dry dendromass t ha^{-1} yr^{-1}
Spacing m	Age year	H m	DBH cm		
1.5×0.3	5	4.1	2.8	32.4	6.5
1.5×0.5	5	4.1	3.0	21.7	4.3
1.5×1.0	5	4.5	3.5	15.9	3.2

It is clear from the data that there is a direct relationship between stem number and attained yield. This finding is based on the results of the first rotation taking the results into consideration at the age of 5. The less the growing space is, the greater annual increment is in oven-dry dendromass. In the experiment the same provenance – common black locust – was used. Therefore, we cannot speak about differences in the structure of woody tissue and density. The closest spacing (1.5×3.0 m) produced the greatest yield (6.5 t ha^{-1} yr^{-1}). This exceeds the yield (4.3 and 3.2 t ha^{-1} yr^{-1}) of the two wider ones by 34% and 51% respectively.

Results of the yield trial of black locust cultivars can be seen in *Table 2* at the age of 5 and 7 years. At the age of 5, the highest yield was produced by the cultivar *'Üllői'* (8.0 t ha^{-1} yr^{-1}), followed by *'Jászkiséri'* (7.4 t ha^{-1} yr^{-1}) and the common locust (6.7 t ha^{-1} yr^{1}). At the age of 7 the order was the following: *'Üllői'* cultivar (9.7 t ha^{-1} yr^{-1}), common black locust (8.4 t ha^{-1} yr^{-1}) and *'Jászkiséri'* cultivar (7.6 t ha^{-1} yr^{-1}).

We disregarded the detailed mathematical statistical analysis because in case of the common black locust spacing trial the effect of the spacing treatments on the increment of dendromass is unambiguously proved. In case of the trial with black locust cultivars the increment of dendromass has been determined not only by the particular cultivar inherited characteristics but by the micro-site conditions as well.

Table 2. Evaluation of the comparative trial with black locust cultivars for energy production (Helvécia 80/A).

Spacing: 1.5×1.0 m

Factors	Mean			Oven-dry dendromass t ha^{-1}	Increment of oven-dry dendromass t ha^{-1} yr^{-1}
Cultivars	age (year)	H m	DBH cm		
'Üllői'	5	6.2	4.9	40.1	8.0
	7	9.3	6.4	68.1	9.7
'Jászkiséri'	5	6.1	4.7	37.1	7.4
	7	8.8	6.2	53.2	7.6
'Nyirségi'	5	5.3	4.2	28.4	5.7
	7	7.6	5.1	46.2	6.7
'Kiscsalai'	5	6.1	4.6	31.1	6.2
	7	8.4	5.9	49.7	7.1
Common black locust	5	6.1	4.7	33.5	6.7
	7	8.2	5.5	59.1	8.4

In the latest case the planting stock was of selected first class quality. The yield obtained from common black locust in the cultivar experiment is higher than the yield attained in the spacing trial. This fact can be attributed to the site condition.

Conclusions

The results of the experiments presented here are preliminary steps in the evaluation of plantations established for energy purpose.

Dendromass yields for plantations can be very promising but show great variation, depending upon site, species, and climatic region. In the USA black locust increment in oven-dry weight of energy plantations from different temperate climate region ranged from 6 to 12 t ha^{-1} yr^{-1} (*Frederick* et al., 1989). First rotation yields are usually lower than succeeding cuts at 7 to 10-year intervals (*Geyer,* 1992). Our trials demonstrated above have verified these statements.

The trials carried out in the planted energy plantations indicate, that is not reasonable to harvest them in the first three years, as the yield in oven-dry weight in the fifth year is twice – three times as much as it is in the third one. Harvesting in a too short time may increase the population of biotic pests, too.

In Hungary, as mentioned above, black locust is the most suitable tree species for establishing energy plantations. Technology improvements in converting wood to energy will increase wood use and help meet the rising global demand for energy. Black locust is planted extensively word wide and has desirable fuel wood characteristics. Its low moisture content enables reduced handling costs and enhances desirability for efficient energy conversion. Black locust is considered the best fuel wood in Hungary, having good combustibility even when wet. Under the country's site conditions the following tree species would also be suitable for this purpose: *Populus, Salix species* and *Ulmus pumilla*. On dry sites, marginal for poplar growth, black locust and poplar produce nearly the same volume. However, the oven-dry dendromass of black locust is higher because of its higher density (*Rédei and Halupa, Veperdi I. and Osváth-Bujtás,* 2004).

On the basis of our experimental results, the quantity of dendromass depends on site, species and cultivars, as well as on the number of stems per hectares. These factors determine the optimum length of the growing cycle, too. The results of the presented experiments are the initial steps in the complete evaluation of plantations and forests established for energy purpose. These results should be confirmed by other experiments to be carried out in similar site conditions and with similar cultivar composition.

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