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Black locust (*Robinia pseudoacacia* L.) Short-Rotation Crops under Marginal Site Conditions

Károly RÉDEI* – Imre CSIHA – Zsolt KESERŰ

Hungarian Forest Research Institute, Sárvár, Hungary

Abstract – The improvement of the reliability of renewable resources and the decline in reserves of fossile raw material in the coming decades will lead to increasing demands for wood material and consequently to a greater role of short rotation forestry (SRF). Particular efforts have been made in Europe to substitute fossils with renewables, in this context the proportion of renewable energy should be increased to 20% by 2020. SRF can be provide relatively high dendromass (biomass) increment rates if the short rotation tree plantations are grown under favourable site conditions and for an optimum rotation length. However, in many countries only so-called marginal sites are available for setting up tree plantations for energy purpose. For SRF under marginal site conditions black locust (*Robinia pseudoacacia* L.) can be considered as one of the most promising tree species thanks to its favourable growing characteristics. According to a case study presented in the paper black locust can produce a Mean Annual Increment (MAI) of 2.9 to 9.7 oven-dry tons ha^{-1} yr^{-1} at ages between 3 and 7 years using a stocking density of 6667 stems ha^{-1}. On the base of the presented results and according to international literature the expected dendromass volume shows great variation, depending upon site, species, their cultivars, initial spacing and length of rotation cycle.

***Robinia pseudoacacia* L. / short-rotation crops / oven-dry stem dendromass**

Kivonat – Rövid vágásfordulójú akácgazdálkodás marginális termőhelyeken. A megújuló energiaforrások megbízhatósági fejlesztése és a fosszilis nyersanyag-tartalékok kimerülése a következő évtizedekben a faanyag iránti igény növekedését és ebből kifolyólag a rövid vágásfordulójú fatermesztés nagyobb arányú térnyerését fogja eredményezni. Európában már történtek bizonyos erőfeszítések a fosszilis energiahordozóknak megújulókkal történő helyettesítésére, ezzel összefüggésben a megújuló energiaforrások részarányának 2020-ra el kell érni a 20%-os arányt. A rövid termesztési ciklusú fatermesztés viszonylag magas biomassza (dendromassza) hozamot nyújt, ha a rövid vágásfordulójú faültetvényeket kedvező termőhelyi körülmények között és optimális vágásfordulóval termesztik. Azonban sok országban csak az ún. határ-termőhelyeken tudnak energetikai célú faültetvényeket létesíteni. Marginális termőhelyi körülmények között rövid vágásfordulójú faültetvény létesítésére az akác (*Robinia pseudoacacia* L.) az egyik legígéretesebb fafaj, néhány igen kedvező termesztési tulajdonságának köszönhetően. A dolgozatban bemutatott esettanulmány alapján az akác 6667 törzs/ha állománysűrűség mellett 3 és 7 éves kor között 2,9–9,7 t/ha/év abszolút száraz faanyagban mért évi átlagnövedék elérésére képes. Az ismertetett eredmények és a vonatkozó nemzetközi szakirodalom alapján a várható dendromassza mennyisége – a termőhelytől, a fafajtól, a fajtától, a telepítési hálózattól és a vágásforduló időtartamától függően – nagy ingadozást mutat.

Fehér akác / rövid vágásfordulójú ültetvények / abszolút száraz dendromassza

* Corresponding author: redei.karoly@t-online.hu, H-9600 SÁRVÁR, Várkerület 30/A.

1 INTRODUCTION

Using renewable natural resources to generate power has been investigated worldwide in the last 2–3 decades as a consequence of oil crisis commencing early in the 1970's. Particular efforts have been made in many countries to substitute fossils with renewables in order to reduce the dependence on fossil oils and also to apply what had been agreed to in the Kyoto protocol.

Short rotation forestry (SFR) is the intensive cultivation of fast growing tree species on agricultural lands for short rotation periods. Forest crops (tree plantations and forest stands), of course, are not the only sources of biomass for energy, though they are among the most efficient in terms of the ratios of energy contained in the harvested crop to total energy input.

According to the EU regulations, the use of renewable energy sources in Europe should be increased by 20% till 2020. Plantations established for biomass (dendromass) production and managed on short rotation in general may contribute to meet the demand of wood for energy purpose as a renewable source.

The major advantages of establishing short-rotation (energy) plantations are:

- they are renewable (continuous) and reproduce repeatedly;
- they provide an alternative for utilizing lands on which agricultural production is temporarily abandoned;
- they are environmentally compatible (protect against erosion) if the right silvicultural techniques are applied;
- they reduce the use of fossil energy sources, which pollute the environment with sulphur and ash;
- the ash of burnt wood can be used as fertilizer for plant crops;
- by establishing large scale energy plantations, the cost of geological research, mine openings and mining can be reduced;
- the plantations can be distributed in the country more uniformly than the fossil energy sources;
- capital for establishment is considerably less and the return on investment shorter than that of the fossil 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.

2 CHARACTERISTICS OF BLACK LOCUST SUITABLE FOR SHORT ROTATION FORESTRY

In Hungary the black locust covered 37,000 ha in 1885, 109,000 ha in 1911, 186,000 ha in 1938 and 415,000 ha in 2010. One-third of black locust stands are high forests, while two-thirds of them are a coppice. In the 1960’s, Hungary had more black locust forests than all the other European countries.

Black locust timber can be used by industry (mining, construction, furniture), agriculture (posts and poles), and black locust stands are the main basis for Hungarian apiculture and honey production. It 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 not proved by black locust. Not only has the species a very high density (690 kg×m^3), but its fast height growth rate, 2–6 cm×day^{-1} in its juvenile stage, places it among the most fast growing plants. With this combination of both high density and volume increment, black locust can achieve impressive dendromass yield when growing on good sites. Moreover, because of its ability to fix atmospheric nitrogen, it requires little or no nitrogen fertilization. Considering the yield criteria (volume and density) and the symbiotic associations of both bacteria and mycorrhizal fungi, black locust offers an excellent opportunity for energy plantations.

Black locust energy forests can also be established by coppicing. Advantages of energy forests of coppice origin are that the cost of establishment is low compared to that of soil preparation, plantation and cultivation. From the developed root system of the previous stand, a large biomass (above-ground dendromass) can be produced within a short time period. The disadvantage is that the distribution of trees in coppice stands is not as uniform as in plantations optimized for energy production. In coppice stands, the quantity of the produced above-ground dendromass is lower and the rotation is highly influenced by the uneven distribution of stems.

More and more agricultural land is set aside without field crops and can be used for energy production plantations. Black locust is one of the best tree species for this purpose, thanks to its excellent properties, such as vigorous growing potential in the juvenile phase, excellent coppicing ability, high wood density, dry matter production, favourable combustibility of its wood, relatively fast drying and easy harvesting and processing (Halupa – Rédei 1992, Halupa et al. 2000).

3 EXPECTED PRODUCTION IN A BLACK LOCUST SHORT ROTATION PLANTATION UNDER MARGINAL SITE CONDITIONS: A CASE STUDY

3.1 Location

Data used in this study came from a short-rotation plantation trial established in Hungary in the subcompartment Helvécia 80A (*N 46^{0}50’28”, E 19^0 37’34”*) in Central-Hungary between the Danube and Tisza rivers. The forest subcompartment has slightly humous sandy soil without ground-water influence. The annual precipitation amounts to only 500 mm in some years, of wich only less than 300 mm comes in the dry summer period. It means that the water supply is a limiting factor. The trial at Helvécia is not one of the best sites available in Hungary but can be considered as an average yield class site for black locust (Rédei – Veperdi 2005, Rédei – Veperdi 2007).

3.2 Material and methods

The trial was established at a spacing of 1.5 m × 1.0 m, with three repetitions and four treatments representing different plant materials: common black locust and four cultivars ‘*Üllői*’, ‘*Jászkiséri*’, ‘*Nyírségi*’, and ‘*Kiscsalai*’. Each treatment corresponds to a plot of 15 by 20 m. One-year-old rooted cuttings were used in the case of cultivars and one-year-old seedlings in the case of common black locust.

Measurements were made at the ages of 3, 5 and 7 years. At each of these ages, all stems on each plot were counted and 10 trees from each plot were randomly selected for destructive sampling, and their volume (v) was determined with Smalian’s formula (Vaan Laar – Akca 1997). The mean tree volume (v_{mean}) was computed as an arithmetic mean of the volume of felled trees. Stand volume (Vha^{-1}) was estimated through multiplication of v_{mean} by stand density (Nha^{-1}). The stem oven-dry dendromass was determined in laboratory by using a drying temperature of 70^{o}C for 72 hours.

Analysis of variance was done for the mean annual increment of oven-dry stem dendromass at age of 7 years.

3.3 Results

Results concerning the trial with cultivars and common black locust at the age of 3, 5 and 7 years are provided in *Table 1* and focused on the differences in the values of the mean annual increment of oven-dry stem dendromass in *Figure1*. At the age of 5, the highest increment value was produced by the cultivar '*Üllői'* (8.0 tons $ha^{-1} yr^{-1}$), followed by '*Jászkiséri'* (7.4 tons $ha^{-1} yr^{-1}$) and the common black locust (6.7 tons $ha^{-1} yr^{1}$). At the age of 7, the order was the following: '*Üllői'* cultivar (9.7 tons $ha^{-1} yr^{-1}$), common black locust (8.4 tons $ha^{-1} yr^{-1}$) and '*Jászkiséri'* cultivar (7.6 tons $ha^{-1} yr^{-1}$).

Table 1. Evaluation of a short-rotation plantation with black locust cultivars on the base of plot averages (Helvécia 80/A); Stem number = 6666 per ha, H=height, DBH= diameter at the breast height (1.3m).

Cultivars	Age	Mean		Oven-dry stem dendromass	Mean annual increment of oven-dry stem dendromass
		H	DBH		
	(yr)	(m)	(cm)	(tons ha^{-1})	(tons $ha^{-1} yr^{-1}$)
'*Üllői'*	3	4.1	3.1	8.9	3.0
	5	6.2	4.9	40.1	8.0
	7	9.3	6.4	68.1	9.7
'*Jászkiséri'*	3	3.6	2.9	7.1	2.4
	5	6.1	4.7	37.1	7.4
	7	8.8	6.2	53.2	7.6
'*Nyírségi'*	3	3.1	2.7	7.2	2.4
	5	5.3	4.2	28.4	5.7
	7	7.6	5.1	46.2	6.7
'*Kiscsalai'*	3	3.9	3.2	12.5	4.2
	5	6.1	4.6	31.1	6.2
	7	8.4	5.9	49.7	7.1
Common black locust	3	3.7	3.1	10.9	3.6
	5	6.1	4.7	33.5	6.7
	7	8.2	5.5	59.1	8.4

The data from the *Table 1* and the *Figure 1* indicate that it is not reasonable to harvest the plantations in the first three years, as the mean annual increment of oven-dry sterm dendromass at the age of 5 and 7 is 1.5–3 times higher than it was at age of 3. This result is important as it is known that too early harvesting may also increase the population of biotic pests (Rédei – Veperdi 2005).

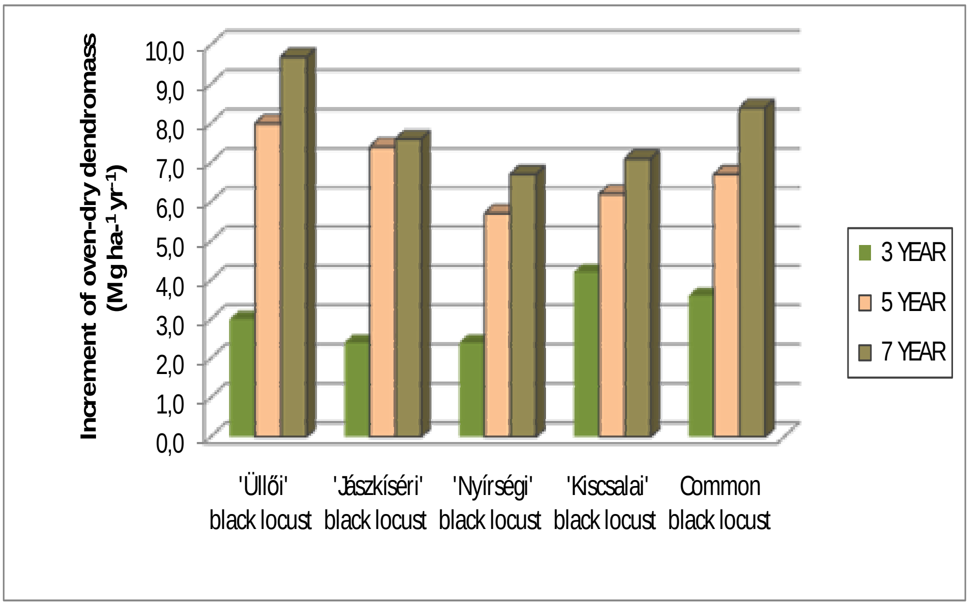

Figure 1. Mean annual increment of oven-dry stem dendromass of black locust cultivars and common black locust at different ages

According to the significance test at P = 5% level, significant differences were found in the mean annual increment of oven-dry stem dendromass ($F=40.991>F_{0.05}=3.422$, $SD_{5\%} = 0.69$ m^{3} ha^{-1} yr^{-1}). When comparing the respective yields produced by the black locust clones and the common black locust, it becomes evident that using expensive black locust clonal material for setting up short rotation plantation has no added value.

4 DISCUSSION AND CONCLUSIONS

Dendromass yields of tree plantations and forest stands for energy purpose can be very promising but show great variation depending upon site, species, and climatic region. From the first experimental results in the 1970's, Canell and Smith (1980) and Pardé (1980) suggested that in most temperate regions it would not be realistic to give field predictions higher than 6 to 8 tons ha^{-1} yr^{-1} of wood dry weight in stems and branches. In some other papers, black locust increment in oven-dry weight of energy plantations from different temperate climate region ranged from 6 to 12 tons ha^{-1} yr^{-1} (Frederick 1989). The trial described in this paper gave also similar results.

Given the large share of marginal arable land in NE - Germany and the predicted climate change, *Robinia pseudoacacia* is expected to grow in importance. In order to evaluate the growth performance of this species under extreme conditions, four experiments were established in the post-mining landscape of the Lusatian lignite-mining district (NE - Germany). Biomass production was estimated for 3- to 14-year-old shoots on 4- to 14-year-old roots. Results for the annual production of oven-dried biomass of *Robinia pseudoacacia* ranged between 3 and 10 tons ha^{-1}, which was substantially grater than the biomass of poplar and willow clones established on the same site. The economic results showed that the cultivation of this tree species was an economically competitive land – use strategy for the post - mining landscapes (Grünewald et al. 2009).

Good results were obtained with black locust (12.5 tons ha^{-1} year^{-1}) in Italy. It proved to be resistant to most pests. In general it required fewer tending operations than poplar and willow (Facciotto et al. 2009).

Table 2 gives the most important structure and dendromass factors of the two black locust short-rotation crops of coppice origin based on stand surveys at the age of 4 in the same forest subcompartment mentioned above in Helvécia, Hungary. Considering that height (H) and mean diameter (DBH) values are almost the same, and thus the mortality resulting in different stand densities must have been responsible for the differences in the stem oven-dry dendromass. The difference of 57% in stand density resulted in a surplus of about 15% in mean annual increment of oven-dry stem dendromass.

Table 2. Evaluation of a short-rotation black locust stand of coppice origin in the trial Helvécia 80/A, N= stem number , H=height, DBH=diameter at breast height 1.3 m

Factors		Mean		Oven-dry stem dendromass	Mean annual increment of oven-dry stem dendromass
N	age	H	DBH		
(ha^{-1})	(yr)	(m)	(cm)	($t\ ha^{-1}$)	($t\ ha^{-1}\ yr^{-1}$)
8333	4	4.8	2.5	31.2	7.8
5306	4	4.7	2.8	27.1	6.8

In Hungary, as mentioned above, black locust is the most suitable tree species for establishing energy tree plantations. Technology improvements in converting wood to energy will increase wood use and help to meet the rising global demand for energy. Black locust is planted extensively world wide and has desirable fuel wood characteristics. It's low moisture content enables reduced handling costs and enhances suitability for efficient energy conversion. Black locust is therefore considered the best fuel wood in Hungary, having good combustibility even when wet.

In short rotation tree plantations, where the average rotation period is 4–5 years, regarding game damage the most critical period is the first 1–2 years (following their establishment). In the case of black locust, main part of game damage is browsing which has a great negative effect of the annual increment, and subsequent dendromass production. It could cause 30–35% shortfall in the mean annual increment. The most effective but most expensive way of game control is game fencing, or if there is a possibility, electric fence.

The results obtained in the experimental plots described in this paper show that the quantity of dendromass strongly depends on the plant material (cultivars) as well as on the number of stems per hectare. These factors are important for the determination of optimum rotation period.

The presented results are the initial step of a more comprehensive evaluation of short-rotation crops established for energy purpose. The preliminary results should be confirmed by other experiments in similar site conditions and with different tree species and/or their cultivars.

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