Distribution and peculiarities of black locust in Romania

Alexandru Liviu Ciuvăţ, Ioan Vasile Abrudan, Viorel Blujdea, Cristiana Marcu, Cristiana Dinu, Mihai Enescu, Ilie Silvestru Nuţă

1.Introduction

Marin Drăcea, a famous personality of Romanian silviculture, whose name identifies with the species itself ("*Drăcea*" means black locust in Bosnian language) (Stinghe & Chiriţă 1978 in Giurgiu 2005), was mentioning the presence of black locust in Romania even before the XVIII century (approximately 1770); however starting with the XVIII century the species has been well-known throughout Valachia (south Romania). According to his research, it seems that black locust was brought into the country by the neighbouring Hungarians, Austrians, Serbs, and Ottomans; the first name of the species in Romanian language being of Turkish origin (*salcmac* = hanging on branch/grape) (Drăcea 1928, 2008).

One of the most important contributions to the scientific knowledge of the species was brought more than 80 years ago (in 1923), when Marin Drăcea published his PhD thesis (*Beitraege zur Kenntnis der Robinie in Rumaenien unter besonder. Berücksichtigung ihrer Kultur auf Sandböden in der Oltenia*). The study contains detailed information on the distribution and the culture of black locust in Europe and Romania, research and data on species morphology, growth, development (especially the heart-wood formation) and productivity of black locust stands, still relevant due to their scientific value.

The first black locust plantation in Romania was made in 1852 and the first reference about it – made by the economist P. S. Aurelian in 1875 – was in the publication „*Tiara nostra*" (in Drăcea 1928, 2008) , whilst the first reference in the foreign literature about black locust in Romania by the French forester G. Huffel, in 1906 (Drăcea 1928, 2008). The first article about black locust published in *Revista Pădurilor* – the oldest Romanian scientific journal belongs to Danilescu (1894). Since then, a number of approximately 150 articles/papers about black locust –have been published in this journal.

2. Geographical distribution

2.1. Global distribution and general information on the species

Black locust (*Robinia pseudoacacia* L.) is a tree reaching heights of over 25 m, native to the eastern part of North America, where it occupies an area of approximately 38 million hectares (area deducted from Brown & Schroeder 1999 and data available at www.fs.fed.us). Nowadays it is cultivated on almost all continents. The species was brought to Europe in 1601, by Jean Robin, a French royal botanist. Some information on the global distribution of black locust based on available data at the time of research, is presented in Table 1, and detailed in the Annex 1.

Table 1. Global distribution of black locust

Continent	Area (ha)	Source
U.S.A. (Eastern part)	38.135.000	http://www.fs.fed.us/ne/delaware/atlas/wtiv_chng901.htm, Oct 1 1999, Brown & Schroeder, 1999
Asia	2.395.000	Keresztesi 1988, de los Angeles Gras 1991, Porojan 2007
Europe	1.389.601	Keresztesi 1988, Benčat 1989, de los Angeles Gras 1991, Capcelea et al. 2011, Maltoni et al. 2012, Rédei et al. 2012
TOTAL (ha)	41.919.601	

2.2. Distribution in Romania

Although fossil fragments of black locust were found in rock layers corresponding to the Tertiary geologic period in Europe (Keller 1900 in Vadas 1914), this species is considered non-indigenous in Romania, the provenance of the first individuals being still debatable.

The area of black locust stands in Romania has increased continuously, reaching nowadays about 250,000 ha (Giurgiu 2005, Șofletea & Curtu 2007, IFN 2012, Neţoiu 2012).

2.2.1. Distribution map of black locust

The *Distribution map of black locust stands within the forest zones in Romania* was developed by updating the *Geospatial forest database of Romania* (finalised in the year 2008) based on the latest data available from the Forest Management Plans (2008-2012 period) for the main distribution regions of black locust: Southern, Western, Central and Eastern Romania. The basis for the map was the *Forest Map of Romania* (Doniță et al. 2008) in which areas with black locust which were not reported before were included and highlighted.

In order to transpose into GIS the Forest Management Plans (scale 1:20 000) containing the black locust stands, several steps were taken: first the cartographic material (maps) was scanned, transferring the data from the hard to the digital format (raster), which in turn were georeferenced based on the 1970 Stereographic projection orthophotoplans (high resolution aerial photographs), recorded in the period 2003-2005. Second step consisted of vectorizing the areas of black locust stands, thus obtaining the area and geographical position of black locust stands at management unit level. These steps allow for processing the data and restore the maps at any scale in GIS format. Final step consisted of analysing the data and calculating the areas occupied by black locust in the main forest zones of Romania. The final product is the map shown in Figure 1.

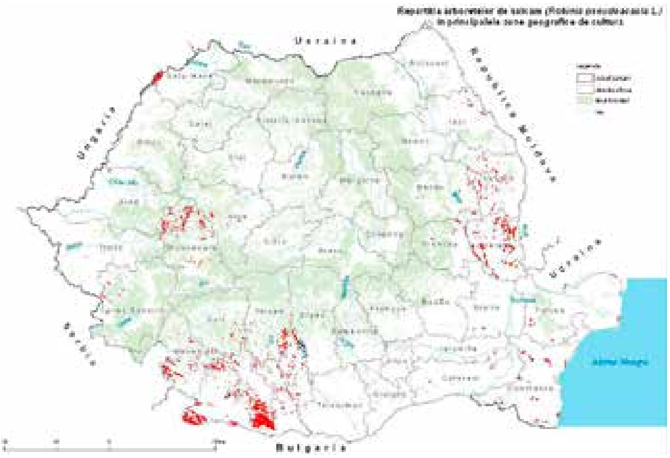

Figure 1. Geographical distribution of black locust stands in the main forest zones of Romania

As it can be seen from Figure 1 and also according to the National Forest Inventory (2012), the species has three major areas of cultivation directly related to soil and climate conditions: in the south of the country (Olt, Dolj, Mehedinți, Gorj, Vâlcea and Argeş counties), in the west (Satu Mare, Bihor and Hunedoara counties) and in the east (Galați, Vaslui and Iași counties) summing up circa 100,000 ha. The other approximately 150,000 ha are spread across all the other 30 counties of the country.

2.3. Silviculture

Although it had been planted by peasants in their households and on the streets of villages for at least 50 years before (Rădulescu 1955), the first large area plantation of black locust was made in 1852. The aim was to stabilize the „flying sands"[1] that were degrading the agricultural lands in that region. Because of the success in stopping the advancement of the sands, the afforestations continued in 1861-1862, then in 1870-1875 at Desa, followed by Piscu Tunari and Ciuperceni in 1883, all located in the south of Dolj County in the Danube River flood plain (Costea et al. 1969a). Thus by the beginning of the XIX century in the southern Oltenia region there were approximately 10000 ha of flying sands stabilized through black locust cultures (Nuță 2007).

The plantations were mainly pure stands (100% black locust) with planting densities ranging from 1 m x 1 m in the case of forest shelterbelts to 1.5 (1) x 1 (1.5) m, and 2 m x 1 (1.5) m for pure stands. For the early plantations, foresters used seed imported from Hungary, Turky, Yugoslavia and Austria (leading to morphological and phonological variety), but they quickly adapted by establishing local nurseries and producing seedlings (Costea et al. 1969a).

Practice has proved that when planted in mixed cultures, (e.g. with oak, honey locust, pine species, bush species) the other species have to be grouped otherwise black locust eliminates them (Cartianu 1906, Traci 1960, Pârvu et al. 1969).

After the end of World War II, all Romanian forests were nationalized in 1948. Under state management the area of black locust stands increased, so that by the year 1962 it reached about 75816 ha, 56% (42687 ha) being concentrated in Oltenia, 35% in the south-east, and 8% in the west of the country (Lăzărescu 1968, Costea et al. 1969a). The problem was that nearly 90% of them were second or third generation coppiced (Milescu & Armăşescu 1960).

National Forest Inventory conducted in 1984 revealed the fact that in only 20 years black locust stands nearly doubled in area, reaching 146,499 ha. This rapid increase started in 1969 with the establishment of forest shelterbelts[2] on 115,500 ha (until 1980) in the Sadova-Corabia region with the purpose of protecting agricultural lands, infrastructure and local communities against wind, snow and sand movement.

Because of its high productivity at early ages, black locust was sometimes planted on high productivity sites replacing native species (especially Quercus sp.), thus diminishing local biodiversity (specific to mixed oak natural forest types) and empowering the soil mineral reserves (Dănescu et al. 2003). One example is given by Popa (2003) about the reforestation of the degraded forests (mostly second/third generation coppiced oak species) in Covurlui Plateau, based on the documents in the archive of Vrancea Forest Office. He shows that the main species used to substitute the native oaks was *Robinia pseudoacacia* wich in many cases was planted on soils types that demanded afforestation according to natural type of forest based on *Quercus* sp. mixed with supporting species (*Fraxinus* sp., *Ulmus* sp., *Tilia* sp.).

In some cases black locust was planted on compact soils, or soils with high concentrations of calcium carbonate in the upper layer, leading to slow growth, low productivities and in many cases to dying of trees. In these situations it is necessary to substitute the black locust with native species adapted to local site conditions like the native oak species (Abrudan 2007).

In 1991 the forest restitution to former owners was initiated, and three restitution laws were implemented[3] successively to

1 „Flying sands" are sand particles moving under the action of wind, leading to the formation of sand dunes

2 Forest cultures in the form of belts of variable width and length placed at certain distance from one-another aimed at protecting an objective against damaging factors (Nuță 2007)

3 Law 18/1991, Law 1/2000 and Law 247/2005

restitute the forests to their owners prior to 1948 nationalization (Abrudan & Ioraş 2006). Through these laws more than 3000000 ha (about 45% of the national forest area) were given back to both individuals and legal entities, thus large areas of black locust stands were transferred to private ownership/management. Unfortunately, in several cases this led to illegal logging and lack of management which resulted in the degradation of thousands of hectares of black locust stands under private ownership (Blujdea et al. 2010).

Nevertheless in 2008, according to NFA statistics[4] the species occupied an area of 155687 ha from the state owned forests (5% of state forests), with another approximately 95000 ha of black locust stands being under private ownership (IFN 2012). This steady increase of the black locust area was mainly due to afforestation carried out by the state and private forest sectors (private forest owners). During 1990-2009 period the National Forest Administration (NFA) afforested 30586 ha of degraded/abandoned agricultural lands and created 1107 ha of forest shelterbelts between the years 2000 and 2009 (Programul Naţional de Împădurire 2010). Considering the site conditions and the form of degradation of these lands, black locust is one of the main species recommended by the Technical Norms for Afforestation in Romania (Norme tehnice 1, 2000). According to NFA statistics[5] 1059 ha were afforested with black locust in the last three years (2010–2012).

Black locust was extensively planted by farmers before (Rădulescu 1955) and after 1990, especially on abandoned agricultural land. In recent years, the species again proved to be the best solution to the re-emerging problem of the „flying sands" in southern Oltenia, where in the last ten years some 5000 ha were afforested (according to local authorities), at the initiative of the local communities (Mârșani, Daneţi and Urzica villages).

The main forest management approach in Romania was to plant *black locust* on degraded lands were native species are not suitable due to very difficult site conditions (except clayey or highly carbonated soils). It is generally planted in pure stands (occasionally mixed with *Gleditsia triacanthos* L.) with rotations of maximum 30 – 40 years, but it can be found isolated in older stands of different species (i.e. oak stands – Table 2).

Table 2. Age class distribution of black locust forests (IFN 2012)

Species	Age class (years)	Area (ha)
Black locust	1-10	75,056
	1-20	79,110
	21-30	41,641
	31-40	29,073
	> 40*	20,732
	uneven-aged stands*	4,927
Total	-	250,539

* Black locust found disseminated in other species stands (i.e. *Quercus* sp. stands)

4 Raport Statistic SILV 1 pe anul 2007, Regia Națională a Pădurilor – Romsilva

5 SILV 4 – Lucrări de regenerare a pădurilor executate în fondul forestier, terenuri degradate și alte terenuri din afara fondului forestier (pentru anii 2010, 2011 și 2012)

3. Ecological characteristics and site requirements

Robinia pseudoacacia L. is a heliophilous species with little shade-tolerance, but slightly tolerates lateral shading, old stands being loose with not much influence on internal climate (Șofletea & Curtu, 2007). As a result of its loose canopy, soils tend to be invaded by herbaceous species, thus it is recommended that soil protective shrub species (e.g. *Sambucus* sp. and *Crataegus* sp.) should be used in the afforestation works (Chiriţă & Munteanu 1932).

Black locust grows well in warm regions with long summers, on the sands / sandy soils like the northwest, southern and eastern parts of Romania, and it's very rarely found in cold regions (mountains) because it is exposed to early frost (which affects the young shoots) and very cold and long winters. Nevertheless it was planted since 1900 in the Apuseni mountains (western part of the Romanian Carpathians), up to 800 m altitude, on steep slopes, as a means of protection against soil erosion, where it showed remarkable resistance to early frost (Traci 1960).

Being a thermophile species, the best site conditions for black locust stands in Romania are in the south of the country, in Oltenia geographical region, as reflected by the research made by Ivanschi et al. (1969) in order to establish the most suitable sites for the cultivation of black locust. It can become *invasive* if planted on sites that it can invade due to its fast growth and vigorous vegetative regeneration (Enescu & Dănescu 2013).

According to Köppen (Stoenescu & Țâștea 1962) climatic classification of Romania, black locust stands from southern Oltenia are included in two climatic provinces: Cfax (II APS_1) and Dfax (II Ap2). The first is characterised by a temperate and humid climate, the hottest summers and the warmest winters of the country, with an annual rainfall of 570 mm, a mean annual temperature of 11.5 ^{0}C, and an annual aridity index of 26.5. The second climatic province (Dfax), is of boreal and wet climate, with harsh winters and hot summers, with an annual rainfall of 519 mm,a mean annual temperature of 11.1 ^{0}C, and an annual aridity index of 24.6 (Ivanschi et al. 1969).

Under the action of the prevailing winds in Oltenia, mobile sands were irregularly accumulated depending on wind strength and size of sand particles, forming dunes perpendicular to the wind direction. In general, the dunes have slopes with lower inclination on the wind direction and more steeper on the opposite.

The sand dunes from south Oltenia have big curls which are quite regular in NW-SE and N-S oriented. The distance between them is 100-500 m, and their height does not exceed 15 m. If the distance from the Danube river is increasing, dune height decreases and the distance between them increases and they stretch over a length of several kilometres (Ivanschi et al. 1969).

Black locust thrives on sandy soils (including sand dunes), or sandy-loamy and loamy-sandy soils, loose to lightly compact, with an available physiologic thickness over 50-60 cm, and with medium humidity regime. It prefers moderate to very rich humus content in the top layer in the case of light and middle texture soils, but grows well also on poor to very humified alluvial soils with an average to high content of nitrogen and phosphorus, eubasic (V>75%), pH neutral to slightly acid, with carbonates below 50-60 cm and without soluble salts up to 100 cm depth. If above 30-40 cm, carbonates have a strong negative influence on the species growth or even survival. Also the presence of soluble salts (chlorides, sulphates) in the soil, especially chlorides, limit the areas in which black locust can survive.

In southern Oltenia region, the sandy soils formed in depressions and on the tops of the dunes, are generally richer in humus than the ones from the north-east of the country (Ivanschi et al.1969).

4. Biological peculiarities

4.1. Morphology

Earlier research on *Robinia pseudoacacia* morphology was conducted by Purcelean (1954) and Sănduleac et al. (1962), focusing on ornamental varieties of the species recommended for parks and alleys, respectively the flower morphology.

Studying the influence of type of regeneration (seeds, sprouts, root suckers) and age on the root system of black locust, Enescu (1960) highlights the fact that after cutting the tree, the number of living roots is directly linked (via physiological processes) to the number of sprouts generated by the stump. He also confirms what practice has proven, namely that after 2-3 coppicing cycles the stump loses very much its capacity to generate sprouts, whilst root suckers benefit from their own root system, are more healthy, and after a certain age they are more productive then stump sprouts.

Seeds colour may vary from tree to tree, and it can by classified in 4 categories: yellowish-brown, greenish-brown, dark brown and even black, associated to different forms and sizes of the pods (Hernea et al. 2009 a). Generally the darker colour seeds have the strongest tegument (Tănăsescu 1969).

After studying 10 different plants for two successive years, Lăzărescu (1969) concluded that the length of the fruit and the number of seeds are variable among individuals; however no significant differences were identified between common black locust and the cultivars *decaisneana* and *unifolia*.

Comparing the *Robinia pseudoacacia* var. *rectissima* to common black locust, Bolea et al. (1995) noticed distinct leaf morphological characteristics, such as: longer rachis (13.5-29 cm), bigger number of leaflets (13 to 19), and larger area leaflets (up to 21 cm^2).

***Robinia pseudoacacia* var. *Oltenica*.** Bârlănescu, Costea and Stoiculescu (1966) succeeded in identifying (in 1961) a distinct population of black locust in South-West Romania (Oltenia geographical region). Based on its morphological characteristics different from that of common black locust (e.g. shoots with very small or no thorns, flowers with very small or no petals, cylindrical trunk, well pruned, narrow crown) this population was defined as adistinct taxonomical variety named *Oltenica* (after the geographical region were it was found) (Stănescu 1979, Șofletea & Curtu 2007, Hernea et al. 2008).

Flowers and leaves variability in *Robinia pseudoacacia* genotypes of south Oltenia was also studied in recent years by Corneanu et al. (2008a, b). Hernea et al. (2009 b) undertook research regarding interpopulational variability and correlation between leaf characters of *Robinia pseudoacacia* var. *Oltenica*, observing differences in leaf characters (rachis length and number of leaflets) for the studied black locust populations and a very significant correlations between these two characters.

4.2. Phenology

Black locust flowering occurs in May-June, in three stages: first on the stands Danube River plain, than in areas located in the Romanian Plain, and lastly those in the hilly regions nearby Carpathians. The flowering is abundant with the separate male and female plants having sweetly fragrant flowers (melliferous) that are creamy white with five petals (bean-like) arranged in a 10-25 cm pyramidal spike. It reaches maturity starting at age of 5 years, producing seeds annually (around September) and abundantly (50000 seeds per kg) (Stănescu 1979), but it's known to flower twice in a year, the second production of seeds having lower capacity to germinate then the first one (Tănăsescu 1970).

4.3. Nutrition

Based on the physiological researches conducted on *Robinia pseudoacacia* and its other American relative – *Gleditschia triacnthos* (honey locust) whom sometimes were planted together in mixed stands, Georgescu (1932, 1933) describes the stomata mechanism, concluding that the diurnal movement of stomata is trigger by external factors rather than leaf morphology. The same author conducted measurements on black locust seedling transpiration, emphasizing that the ratio between fresh and dry leaves mass acts as an indicator of this process.

Black locust consumes large quantities of minerals from the soil, which has a negative effect on species growth when it is planted on poor soils (it also drains the soil) (Enculescu 1919, Chiriță 1933, Șofletea & Curtu 2007). Field experiments and practice proved that adding mineral fertilizers can lead to an increase of survival rate (saplings ha^{-1}) of up to 56%. Visual diagnosis of mineral deficiency in nutrition can be done based on leaf colour, size and appearance: e.g. in case of phosphorus (P) deficiency brown spots can be seen on the leaves and in the case of nitrogen (N) deficiency the leaves are smaller than normal and pale green (Costea et al. 1969b).

Constantinescu et al. (1970) highlighted the role of minerals in black locust nutrition by using radioactive isotopes. In an experiment, black locust seedlings were subject to different nutritional conditions, by adding following fertilizers: N (33%), P_2O_5 (18%), K_2O (36%) and CaO (90%). Results showed that contrary to expectations nitrogen (N) fertilization plays a secondary role in the nutrition of black locust, while phosphorus (P) fertilization plays a crucial role, increasing the growth by up to 20% compared to normal conditions.

Chemical analysis of leaves and bark revealed a higher concentration of minerals compared to the stem and roots, with P, K and Ca concentrated towards the terminal bud and young shoots.

By using Boysen – Jensen method Bolea et al. (1995) determined for *Robinia pseudoacacia* var. *rectissima* a photosynthetic intensity of 92.5 mg CO_2 $g^{-1}h^{-1}$ (real photosynthesis at age 17), and photosynthetic efficiency of 52.7-96.2%, which are higher than in any Romanian native species. The results showed that compared to common black locust stands, the *Robinia pseudoacacia* var. *rectissima* trees show also greater resistance to drought.

Black locust is a nitrogen (N) fixing plant (Fabaceae / Leguminosae Family) which through symbiosis with nitrogen fixing bacteria (*Rhizobium leguminosum*) forming nodules attached to its roots, can capture atmospheric N, thus modifying soil properties (Parascan & Danciu 2001).

Constantinescu et al. (1970) analysed the nitrogen nutrition of black locust seedlings, using micro – Kjeldal method. Results confirmed that atmospheric N fixed by *Rhizobium leguminosum* bacteria, has a major role in the species N nutrition. Nevertheless applying mineral nitrogen based fertilizers improves overall mineral nutrition leading to increase in height, diameter and biomass accumulation of up to 14%.

Corneanu et al. (2009) analysis of the ultrastructural features of the leaves of *Robinia p.* planted on the sterile waste dump in Rovinari (Gorj county), and in the control plantation of Arginesti Orchard (Mehedinti county) underlined the active implication of this species in the heavy metal or/and radionuclide neutralization.

4.4 Growth

Robinia pseudoacacia L. is a fast growing species, which can reach heights of 6 m in the first season (in the case of sprouts) and heights of 30 m at the age of 30-35 years, with basal diameters of 30 cm at 15 years (Drăcea 1928, 2008), depending on site conditions and type of regeneration.

At ages around 20 years, plantations found in optimal site conditions can reach yields of 15-17 m^3 an^{-1} ha^{-1}, while the best stands regenerated from sprouts at the same age can accumulate 13-14 m^3 an^{-1} ha^{-1} (Șofletea & Curtu 2007).

Drăcea (1928) was the first Romanian to undertake thorough research about diameter and height growth, producing detailed yield and volume tables for black locust coppice stands from Oltenia. He also investigated wood formation processes, percentage of bark and hardwood, wood specific weight and trunk shape.

Stinghe & Toma (1937) developed volume tables, form coefficients and reduced heights for the black locust from Ciuperceni Forest Range, which were the first real volume tables for this species, due to the high number of measured trees (1858 individuals) and the calculation method employed.

Improvements to the existing volume tables were made by Armășescu & Decei (1958) by including the secondary stand (trees to be extracted through tending operations) into calculations and establishing the natural growing series.

The rate of growth evolves differently in the case of sprouts and root-suckers compared to the planted seedlings and also in the case of pure compered to mixed cultures (Huber 2007). Analysing the differences Milescu & Armășescu (1960) concluded that root suckers come closest to plantations in terms of growth (89%), health and wood quality. On the other hand, first generation sprouts achieve productivity of around 80% of that of plantations, while second and third generation drops to 65%, respectively 45%. The latter shows also diminished health, lower densities and poor quality wood.

Comparing growth of two stands of black locust with that of one stand of oak and one stand of European black pine (all planted on sandy soil), Armășescu & Tănăsescu (1962) argue that the last two species can achieve similar productivities and have longer life spans than black locust.

Biometry of black locust is reflected in the volume and yield tables (figure 2) which were developed by Giurgiu et al. in 1972, and afterwards used by foresters in managing black locust stands until 2004, when improved tables where edited (Giurgiu et al., 2004a, b).

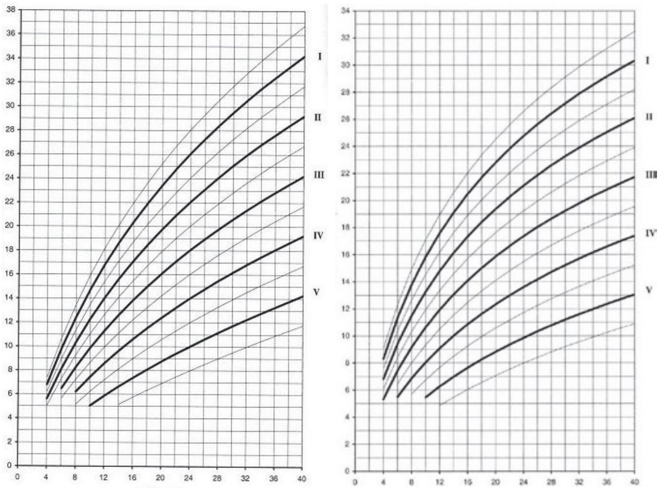

Figure 2. Black locust yield graphs (from seedlings – left; from sprouts – right) for determining yild class (I, II, III, IV, V). Vertical axis – height (m), Horizontal axis – age (years) (Giurgiu et al., 2004 b)

Biomass accumulation

Dissescu & Dissescu (1972) found a strong correlation between dry mass of leaves and total leave area (all the leaves in the crown). The calculated ratio between the two parameters is 19.34 and remains constant regardless of age and size. The authors obtained regression equations for estimation of the total leave area as a function of any of the following parameters: area of horizontal projection of the crown, apparent volume of the crown or exterior area of the crown (measurable from ground level).

Allometric equations for black locust were developed by Blujdea et al. (2012) by means of destructive sampling, in black locust plantations established on degraded agricultural lands from south, south-east and east Romania. Since the biomass expansion factors (BEF) represent a compromise to estimate the total biomass, the authors showed that the allometric equations give a more realistic distribution of biomass at tree level (on components). Especially for small trees, using equations instead of BEF can improve the biomass estimation accuracy by combining data from national forest inventories. Analysing root collar diameter (DCH), shoot basal diameter (DBH – diameter measured at 1.3 m) and tree height (H) as predictors for biomass, the authors found that DCH provided the most accurate estimates. The equations were also validated on three independent datasets, nonspecific data analysis (generalized equation) showing a general overestimation for the aggregate biomass and underestimation for branches and roots, values still falling within the estimated values of the coefficients a and b . The authors conclude that at least for the young trees (DBH <15 cm), developed equations can be applied without taking into account the site quality or the plantation management. Based on the biomass allometric equations for the species used in afforestation (including black locust) the following carbon accumulation[6] graph was drawn (Figure 3):

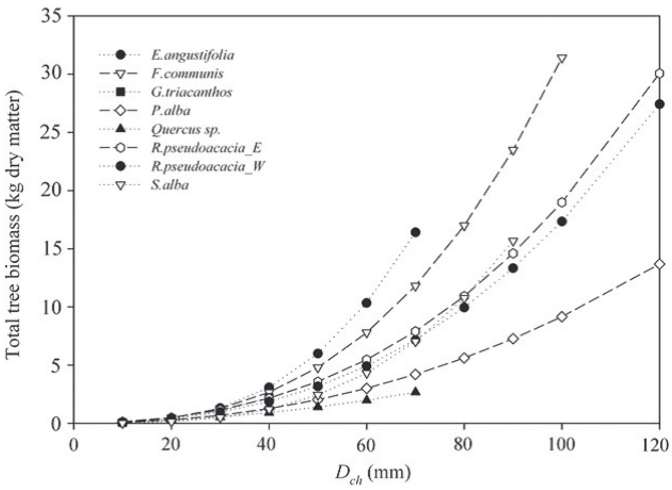

Figure 3. Carbon accumulation by species used in afforestation of degraded lands (Blujdea et al. 2012)

4.5 Wood structure and characteristics

After measuring bark thickness on 104 trees of ages from 7 to 19 years, Drăcea (1928, 2008) concluded that black locust bark covered up to 26% of total tree volume. Assuming that a large proportion of mineral substances absorbed by *Robinia pseudoacacia* are stored in the bark, Drăcea (1928, 2008) suggested that a possible solution to prevent soil mineral reserves depletion would be to leave on site the bark and small branches after trees are cut.

Both Drăcea (1928, 2008) and Marinescu (1937) underlined that in the case of *Robinia pseudoacacia* the percentage of hardwood reached 60% at ages above 20 years, being the highest in the case of isolated trees and of those found on poor sites. Isolated trees have also higher percentage of sapwood and greater wood density. Decei & Armăşescu (1959) and Bereziuc et al. (1976) also studied black locust bark proportion and thickness and concluded it had the highest percentage compared to the Romanian native species.

Vintilă & Galbenu (1944) described black locust wood characteristics with regard to formation of thylle, size of vessels, medullary rays and fibres.

Corlăţeanu (1983) highlighted the physical and chemical properties and the possibilities of capitalization of the black locust secondary liber (bast) and bark, resulted from harvestable stands. Based on his PhD thesis results Corlăţeanu concluded that black locust liber contained 35.9 – 44.3% cellulose, 14.2 – 20.6% lignin and 5.9 – 9.2% mineral substances, while the bark contained 46.2 – 48.1% lignin, 18.85 – 22.1% cellulose, and 8.7 – 12.1% mineral substances. The mineral substances found in the liber and bark were: Ca, P, K, Mn, Fe, Zn, Cu and other minerals in smaller quantities. Corlăţeanu found the average carbon percentage in lignin of 64.4%, and 44.4% in cellulose.

Drăcea (1928, 2008) calculated the average fresh wood density between 724 and 930 kg/m^3 with a mean of 838 kg/m^3, based on measuring fresh weight and volume of black locust of ages between 7 and 15 years. Vintilă (1944) gave a density of 780 kg/cm^3 at a relative wood humidity of 20%, while Hernea et al. (2009 a) determined the following wood densities for *Robinia pseudoacacia* var. *Oltenica*: anhydrous state density between 0.634 and 0.785 g/cm^3, conventional density between 0.532 and 0.648 g/cm^3, and dry wood density between 0.680 and 0.791 g/cm^3.

The wood of *Robinia pseudoacacia* L. is appreciated for its high durability to rot and humidity (Rişcuţă 1977). After testing the natural durability to wood destroying (xylophagous) fungi of black locust and oak (*Quercus robur* and *Quercus petraea*) wood, Vintilă (1944) published the data presented in Table 3.

Table 3. Black locust and oak wood natural durability to xylophagous fungi (Vintilă, 1944)

Xylophagous fungi testing	Durability ratio (%)		Durability class (Bavendamm 1939)	
	Oak	Black locust	Oak	Black locust
Trametes versicolor	95 (93)	94 (98)	Very durable	Very durable
Coniophora puteana	85	68	Very durable	Very durable
Serpula lacrymans	93	75	Very durable	Durable
Daedalea quercina	97	98	Very durable	Very durable

Shear strength of black locust wood differs among populations from South and North Romania, the southern provenances showing higher values for longitudinal and cross section resistance while the northern ones for tangential direction (Porojan 2011). The author mentions that the shearing strengths of black locust wood from Romania (South and North) are generally higher than those indicated by reference literature for oak and beech. This recommends black locust wood as a valuable construction wood and for other applications where wood is subject to shearing stress.

The most common wood defects in the case of black locust are checks, splits and warping (Secărescu 1938).

Seeds and bark contain toxic substances (*robinin, toxi-albumines*) but no cases of human intoxication caused by black locust have been reported in the national literature. Leaves are occasionally used as forage for domestic chicken, rabbit and goats, and also eaten by hares and deer, but can be slightly toxic to humans (Bojor 2003).

4.6. Regeneration

A. Natural regeneration. Black locust regenerates naturally, both sexually – through seeds, as well as vegetatively – from stump sprouts and root suckers. Vegetative regeneration is very often preferred to the sexual one, because it (naturally) occurs easier and costs less, while special conditions and longer periods are needed for the seeds to germinate,

6 ***a*** = intercept, ***b*** = slope

due to the thick and impermeable tegument (Rădulescu & Dămăceanu 1953).

Sexual regeneration. Al though it produces seed annually and quite abundantly, they require special treatment/forcing (chemical, scarification or boiling) in order to have high germination percentages (Lupe 1960, Radu & Bakoş 1973). The main reason why sexual regeneration is difficult even in the natural range of the species is the thick seed coat (tegument) with very low permeability (Demetrescu 1939, Tănăsescu 1970). In some isolated cases it was reported that black locust regenerated naturally from seed in South and Central Romania (Cirin & Anca 1955, Tănăsescu 1961, Tănăsescu 1967, Filip 1963, Olteanu 1968, Tănăsescu & Beloiu 1972).

Vegetative regeneration. The sprouts are generated by the dormant buds of the stem, while the root suckers result from dormant (adventive) buds after mechanical injuries suffered by either the stem or the roots. In the first 10-15 years sprouts and root suckers grow faster than seedlings, but after this time seedlings intensify their growth and surpass the other two in terms of biomass accumulation and longevity. After successive vegetative regeneration both sprouts and root suckers are affected by wood destroying fungi which go up the tree, starting with the root system. Root suckers are generally healthier than sprouts which are affected by rot earlier because of the roots they inherited from the old stump. The majority of root suckers are generated by roots located 15-20 cm deep in the soil. A consequence of the excessive vegetative regeneration it that with every generation the genetic structure weakens by the loss of variability and production drops to 38% compared to plantations (Bârlănesu et al. 1963).

B. Artificial regeneration. Black locust can be propagated by seedlings obtained from seeds, cuttings, graftings or by using *in vitro* micropropagation biotechnology.

Propagation by cuttings. In order to improve selection and obtain valuable cultivars, vegetative propagation by cuttings has the following advantages: the tree forms its own roots (the influence of rootstok is eliminated), it can be done on a large scale in short periods of time, the technology is simple and cost-effective (Lăzărescu et al. 1961).

Lăzărescu et al. (1963) described the results of a polyfactorial experiment with variants referring to cuttings origin (root/stem) and size, cultural technique and propagation time. The survival rate after one year of vegetation showed significant differences concerning the origin and the size of the cuttings. The best root development was for root cuttings 15 to 20 cm long, planted immediately after harvesting, before the start of the growing season. In the situation in which the cutting will be planted few days after harvesting, they must be kept at cool temperatures. Planting distance in the nursery is 20 x 60 cm (Lăzărescu 1968).

Propagation by grafting. Trees obtained from grafting inherit the exact genetic structure, resistance to parasites and form of the mother-trees, and reach maturity after the first year, flowering regularly and abundantly. Grafting is recommended especially to obtain or propagate selected clones of black locust, or to establish seed orchards (Costea et al. 1969b). It is recommended to do the grafting in April, under the bark, using grafts freshly cut from young trees (Enescu et al 1962). Survival rate varies from 35 to 90% depending on the quality of grafts and grafting technique.

***In vitro* micropropagation.** Based on research carried out at the Forest Research and Management Institute in Bucharest, Enescu (1989, 1991) developed an *in vitro* micro-propagation biotechnology. He drew up a breeding programme for black locust, based mainly on clonal selection and vegetative multiplication (especially grafting) of reproductive materials of high biological value. Micro-propagation technology allowed for high multiplication ratio in much shorter time than by conventional methods. The breeding programme sequences are still adequate to the species biological particularities and sustain genetic diversity.

5. Conclusions

With an area of approximately 250,000 ha, black locust occupies almost 4% of the national forest area, being one the most important species used for degraded land reclamation, beekeeping and by private owners who want to afforest their lands (by agroforestry or to produce fuel wood in the lowlands).

The present work tried to summarise the most important results of research focused on black locust distribution in Romania and also on the species ecology and biology.

Based on the *Geospatial forest database of Romania* and the *Forest Map of Romania* (Doniță et al. 2008) the *Distribution map of black locust stands within the main forest zones in Romania* was developed by updating and completing the available data. The methodology combined techniques from the field of *Geomathics* with solid cartographic support consisting of aerial photographs and high resolution satellite imagery.

The species high adaptability on poor sites, fast growth, exceptional sprouting capacity and durable wood, recommend black locust as an ideal species for degraded land reclamation, or (if taking into account more recent trends) for energy crops. Nevertheless the very attributes that give the species its edge on degraded lands can turn it into an invasive neophyte if planted in the wrong sites (sites favourable to other more valuable native species).

The previous researches cited in this paper offer a wide and comprehensive view to foresters engaged in better understanding and management of black locust in Romanian forestry.

ACKNOWLEDGEMENT: This paper is supported by the Sectorial Operational Programme Human Resources Development (SOP HRD) ID76945 financed from the European Social Fund and by the Romanian Government. ■

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*** Jurnal electronic BioDat, 2003

Appendix 1. Black locust forests worldwide

Region/Country	Area (ha)	References
Eastern U.S.A.	38.135.000	http://www.fs.fed.us/ne/delaware/atlas/wtiv_chng901.htm, Oct 1 1999, Brown Sandra, SCHROEDER P. E., 1999
China	1.000.000	Maria de los Angeles Gras 1991
South Korea	1.217.000	Keresztesi 1988
North Korea	178.000	Porojan 2007
Hungary	415.000	Redei et al. 2012
Romania	250.000	IFN 2012
Italy	233.553	Maltoni et al. 2012
France	131.000	Maltoni et al. 2012
Republic of Moldova	131.000	Capcelea et al. 2011
Bulgaria	73.000	Keresztesi 1988
Russian Federation	54.700	Jurnal electronic BioDat, 2003
Former Yugoslavia	50.000	Keresztesi 1988
Slovakia	34.348	Benčat 1989
Germany	8000	Keresztesi 1988
Spain	3000	Keresztesi 1988
Argentina	3000	Keresztesi 1988
Great Britain	3000	Maria de los Angeles Gras 1991
TOTAL (ha)	41.919.601	

Abstract

Distribution and peculiarities of black locust in Romania

The present work aims to bring forward an updated review of the research undertaken in Romania regarding black locust (*Robinia pseudoacacia* L.). Since 1852, after the first black locust plantations were established in south west of the country, foresters and other researchers published more than 150 articles and papers regarding aspects like biology, ecology, genetics, distribution, culture, and multiple uses of this remarkable species. After more than 150 years "in service" of the Romanian forestry, black locust is considered naturalized, earning its place as one of the most important species used to reclaim and restore degraded lands all over the country. Nevertheless its invasive capacity has been studied and accounted for, black locust being planted only on degraded lands. A multipurpose species with numerous benefits aside it's durable wood, it has great value for beekeepers and farmers alike.

Keywords: black locust, ecology, biology, culture, regeneration.