

# FIRST-YEAR BIOMASS PRODUCTION AND SOIL IMPROVEMENT IN *LEUCAENA* AND *ROBINIA* STANDS UNDER DIFFERENT POLLARDING SYSTEMS

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**YOUKHANA, A. & IDOL, T. 2008. First-year biomass production and soil improvement in *Leucaena* and *Robinia* stands under different pollarding systems.** The study of biomass production and soil improvement of two fast growing and multipurpose trees, *Leucaena leucocephala* and *Robinia pseudoacacia*, was carried out in Mosul Forest, northern Iraq, to examine the impact of pollarding height (0, 15, 30 and 45 cm) and frequency (no pollarding, pollarding every three or six months) on growth responses and soil properties. These species are being studied as part of a larger research programme to develop novel agroforestry systems in Iraq. *Leucaena leucocephala* showed the greatest response in terms of branching, shoot basal diameter, height, biomass and nitrogen and phosphorus contents of leaves and stems with pollarding every three months at 15 cm. For *R. pseudoacacia*, pollarding once after six months at 45 cm resulted in the greatest growth response of leaves and stems. Physical soil properties such as bulk density, infiltration rate and chemical properties such as pH, total soil organic matter and nitrogen, available potassium and phosphorus were all improved under *L. leucocephala* and *R. pseudoacacia*. Management of these trees in Iraq for soil improvement or in agroforestry systems with different crops such as wheat, barley, corn and cotton should take into consideration optimal pollarding frequency and height as well as planting density to produce the desired levels of shade, soil cover and green manure, as well as animal fodder or wood products.

Keywords: *Leucaena leucocephala*, *Robinia pseudoacacia*, agroforestry system, soil properties, tree management

**YOUKHANA, A. & IDOL, T. 2008. Penghasilan biojisim dan penambahbaikan tanah pada tahun pertama pertumbuhan dirian *Leucaena* dan *Robinia* di bawah sistem cantasan yang berbeza.** Kajian tentang penghasilan biojisim dan penambahbaikan tanah dijalankan terhadap dua pokok pelbagai guna yang cepat tumbuh iaitu *Leucaena leucocephala* dan *Robinia pseudoacacia* di Hutan Mosul, utara Iraq. Ini bertujuan untuk mengkaji kesan ketinggian mencantas (0 cm, 15 cm, 30 cm dan 45 cm) serta frekuensinya (tiada cantasan, cantasan setiap tiga bulan atau enam bulan) terhadap gerak balas pertumbuhan dan ciri tanah. Kajian kedua-dua spesies ini merupakan sebahagian daripada satu kajian yang lebih besar untuk membangunkan sistem perhutanan tani di Iraq. *Leucaena leucocephala* menunjukkan gerak balas yang paling besar dari segi pencabangan, diameter pangkal pucuk, tinggi, biojisim dan kandungan nitrogen serta fosforus daun dan batang setelah dicantas setiap tiga bulan pada ketinggian 15 cm. Bagi *R. pseudoacacia* cantasan sekali selepas enam bulan pada 45 cm menghasilkan gerak balas pertumbuhan daun dan batang yang terbanyak. Ciri fizikal tanah seperti ketumpatan pukal, kadar penyusupan dan ciri kimia seperti nilai pH, jumlah kandungan jirim organik tanah serta kandungan nitrogen, kalium tersedia dan fosforus semuanya didapati bertambah baik di bawah *L. leucocephala* dan *R. pseudoacacia*. Pengurusan kedua-dua pokok ini di Iraq untuk menambahbaik tanah atau untuk sistem perhutanan tani dengan tanaman lain seperti gandum, barli, jagung dan kapas harus mengambil kira frekuensi cantasan dan ketinggian optimum dan juga ketumpatan tanaman. Ini dapat memastikan agar aras naungan, penutup tanah dan baja hijau yang dikehendaki dapat dicapai selain daripada menghasilkan makanan ternakan dan keluaran kayu.

## INTRODUCTION

The maintenance of soil fertility, and therefore of crop productivity, is crucial to the development of sustainable agriculture. Modern agricultural systems depend heavily on large inputs of

chemical fertilizers for maintenance of crop productivity. On a global scale, the cultivation of nitrogen-fixing trees is of increasing importance in agroforestry systems to improve soil nitrogen

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availability and promote soil conservation (Russo & Budowski 1986). This reduces the need for fertilizer and supports organic production. Many nitrogen-fixing trees are suitable as animal fodder or may produce seeds and pods that are edible for human consumption. Most species can be used as fuelwood, and some produce valuable timber. If pruned, they provide green manure that improves soil cover, suppresses weeds and increases organic matter and nutrient return to the soil.

*Robinia pseudoacacia* (black locust) is native to the south-eastern North America, yet worldwide the land area covered by black locust stands has enlarged dramatically to about 3 million ha, an area only exceeded by that of *Eucalyptus* and *Populus* species (Hanover *et al.* 1991). Black locust is a multipurpose tree that is used in erosion control and reclamation of disturbed areas (Chang-Seok *et al.* 2003). It is tolerant against drought, has excellent wood properties (DeGomez & Wagner 2001), is easy to regenerate from root suckers, grows efficiently on poor sites and improves nitrogen supply and element recycling (Ntayombya & Gorden 1995). Depending on stand age and density as well as on climatic conditions, *R. pseudoacacia* fixes 35–150 kg N ha<sup>-1</sup> year<sup>-1</sup>, indicating a high capacity for N<sub>2</sub> fixation (Danso *et al.* 1995).

*Leucaena leucocephala* is a fast growing, ubiquitous tropical legume which has found use in agroforestry, soil improvement (Lalljee *et al.* 1998), land reclamation, wood and forage production due to its exceptional capacity to produce biomass (Danso *et al.* 1992). *Leucaena* yields of > 15 Mg ha<sup>-1</sup> year<sup>-1</sup> have been reported in South-East Asia and Hawaii, with plants spaced 0.5–1.0 m apart in rows 1–3 m apart (Brewbaker 1987). It has been shown to improve soil fertility due to high biomass production, high nitrogen fixation rate (100–500 kg N ha<sup>-1</sup> year<sup>-1</sup>), and high foliar concentration of N, P, K and Ca (Young 1991).

Some of the plant management issues to be considered in agroforestry and soil improvement systems using these trees include planting density, pollarding frequency and pollarding height. Although some studies have been conducted on pollarding height and frequency, there are still gaps in the available knowledge. Burner *et al.* (2006) studied the effects of harvest date and pollarding height on foliar and shoot allometry of black locust trees; they found that there was a

large increase in basal shoot diameter and foliar and shoot mass for pollarded trees. Depending on row configuration, black locust yielded 900–5000 kg dry matter ha<sup>-1</sup> year<sup>-1</sup> of pruning (foliage plus shoot) biomass in Oregon, USA (Seiter *et al.* 1999).

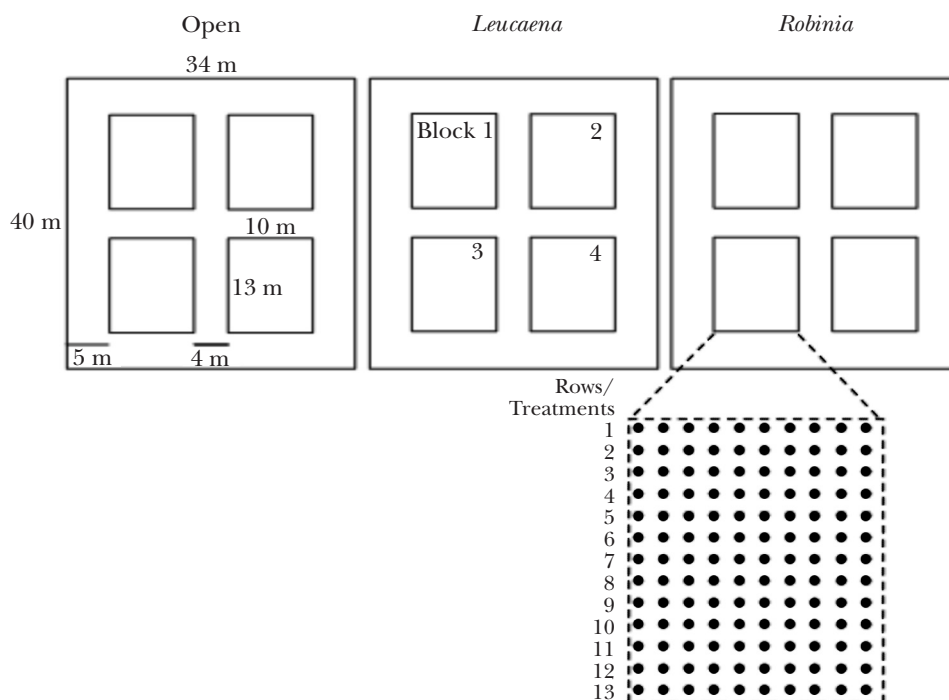
For Iraq, *L. leucocephala* and *R. pseudoacacia* show promise for green manure production and decreasing the demand for mineral fertilizers that have been used in huge quantities recently. This could reduce soil erosion and nutrient leaching and reduce the need for expensive external inputs to farming systems. The objectives of this study were to address the following questions: (1) What are the effects of pollarding frequency and height on the growth performance of *L. leucocephala* and *R. pseudoacacia* trees? (2) Do these trees improve soil organic matter and nutrient status? (3) What is the optimal pollarding height and frequency to maximize biomass production and nutrient concentration of pruned shoots and leaves?

## MATERIALS AND METHODS

The experiment was carried out in Mosul Forest, a part of Mosul city located along the Tigris River in northern Iraq (36° 35' N, 43° 3' E and 222 m asl). Mean annual rainfall ranges from 300 to 600 mm (mean 400 mm), and the mean monthly temperature ranges from 17.2 °C in January to 32.0 °C in July. The soil in this area is derived from alluvial deposits from the Tigris River and has a sandy loam texture.

Three adjacent fields normally used for propagation of tree seedlings were used for this experiment beginning September 2003. Each field was 34 × 40 m. Each field was split into four blocks, each 10 × 13 m. There was a 5-m buffer between the outside edge of each block and the edge of the field and a 4-m buffer between adjacent blocks (Figure 1).

The first field was left unplanted as a control for comparison of soil properties at the beginning and end of the experiment. The second field was planted with one-year-old seedlings of *Leucaena leucocephala*, and the third field was planted with one-year-old seedlings of *Robinia pseudoacacia*. Seedlings were planted in September 2003 in rows at 1 × 1 m spacing. Each block contained 13 rows of seedlings with 10 plants per row. Individual pollarding treatments were randomly assigned to an entire row within each block.



**Figure 1** Layout of the experiment

In January 2004, all the tree seedlings were clipped at a uniform height of 0.5 m above ground level. In March 2004 four pollarding height treatments were applied by clipping seedlings at ground level, 15, 30 or 45 cm. Within each height treatment, trees were assigned to one of three pollarding frequencies: no pollarding, pollarding once after 6 months or twice at 3-month intervals. One row in each block was left as a control without any pollarding after January 2004.

Shoots of individual trees were sampled at the time of pollarding (June and September 2004) and at the end of the experiment (December 2004). Biomass growth was calculated as the total biomass accumulated from the beginning of the growing season (March 2004). The number of shoots per plant was counted and shoot basal diameter was measured with a caliper 5 cm from the distal end. Shoot height was measured with a haga altimeter. Samples of leaves and stems were collected for each species to determine N and P contents. Samples were oven-dried at 70 °C and milled to 0.5 mm. Samples were digested with 18 M sulphuric acid (Anderson & Ingram 1993). Digests were analyzed for total organic N by a micro-Kjeldahl method (Bremner & Mulvaney 1982). Phosphorous was measured colorimetrically by the molybdate blue method (Olsen & Dean 1965).

Soil physical properties bulk density ( $\text{kg m}^{-3}$ ), particle density ( $\text{kg m}^{-3}$ ), percent porosity, infiltration rate ( $\text{kg cm}^{-2}$ ), particle size distribution (percent sand, silt and clay) and soil nutrient status under both species and the open field were analyzed at the beginning and end of the study. Analyses were conducted following the techniques of Anderson & Ingram (1993). Available P and K were measured by atomic adsorption spectroscopy while total soil nitrogen was analyzed by digestion as described above. Extractable ammonium and nitrate were determined using selective ion electrodes.

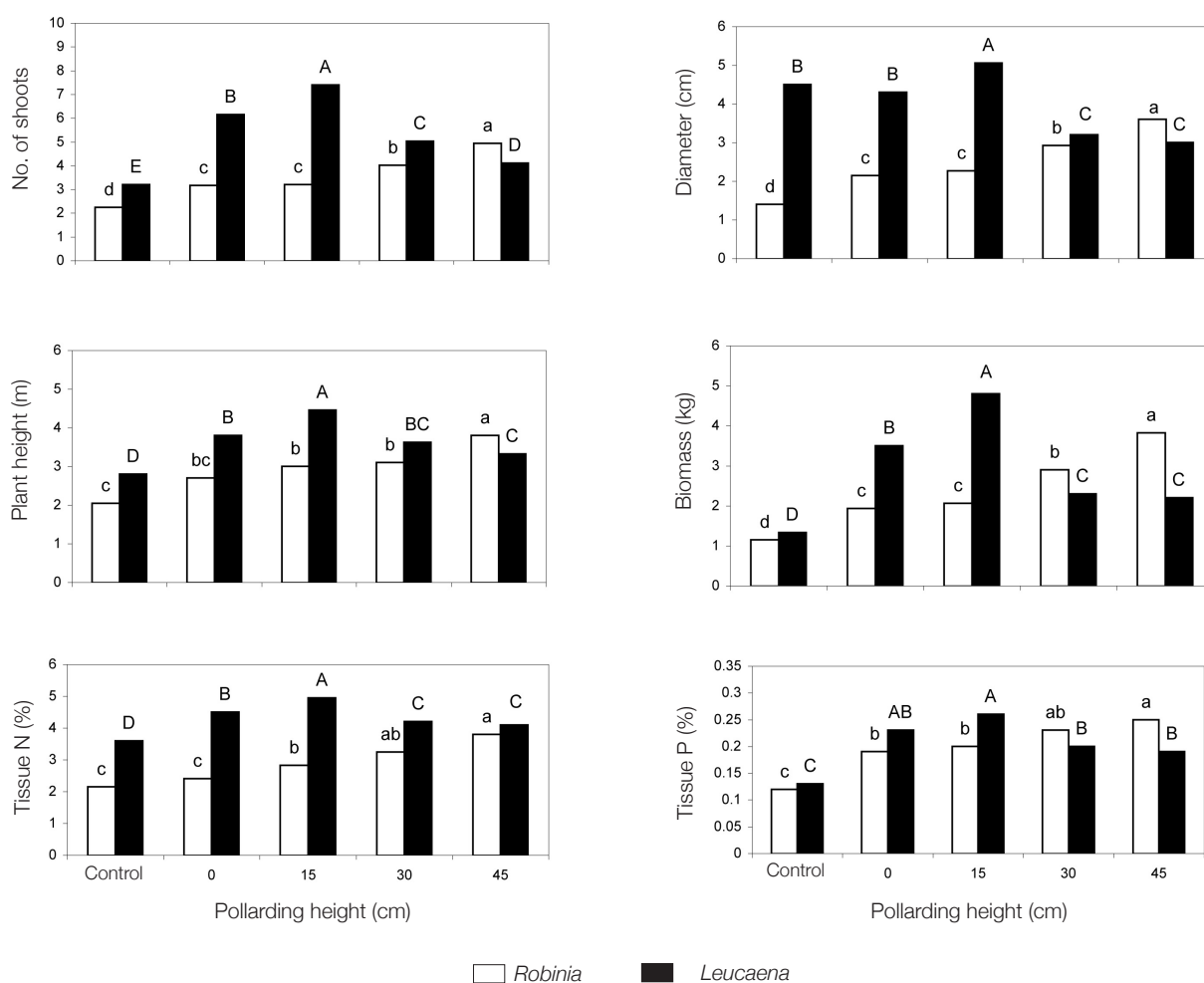
The experimental design was a randomized complete block with two factors (pollarding height and frequency), four replicates of each treatment, and 10 plants in each replicate. For analysis of tree growth response and nutrient concentration, species were analyzed separately. For analysis of soil properties, treatments were combined within blocks and comparisons were made between the two species and the control. The data were log-transformed to achieve a normal distribution. Analysis of variance was used to analyze the log-transformed data (SAS Institute 1998). Duncan's multiple range test was used to compare treatment means, with a significance level of  $p < 0.05$ . Back-transformed data are reported in the results.

## RESULTS

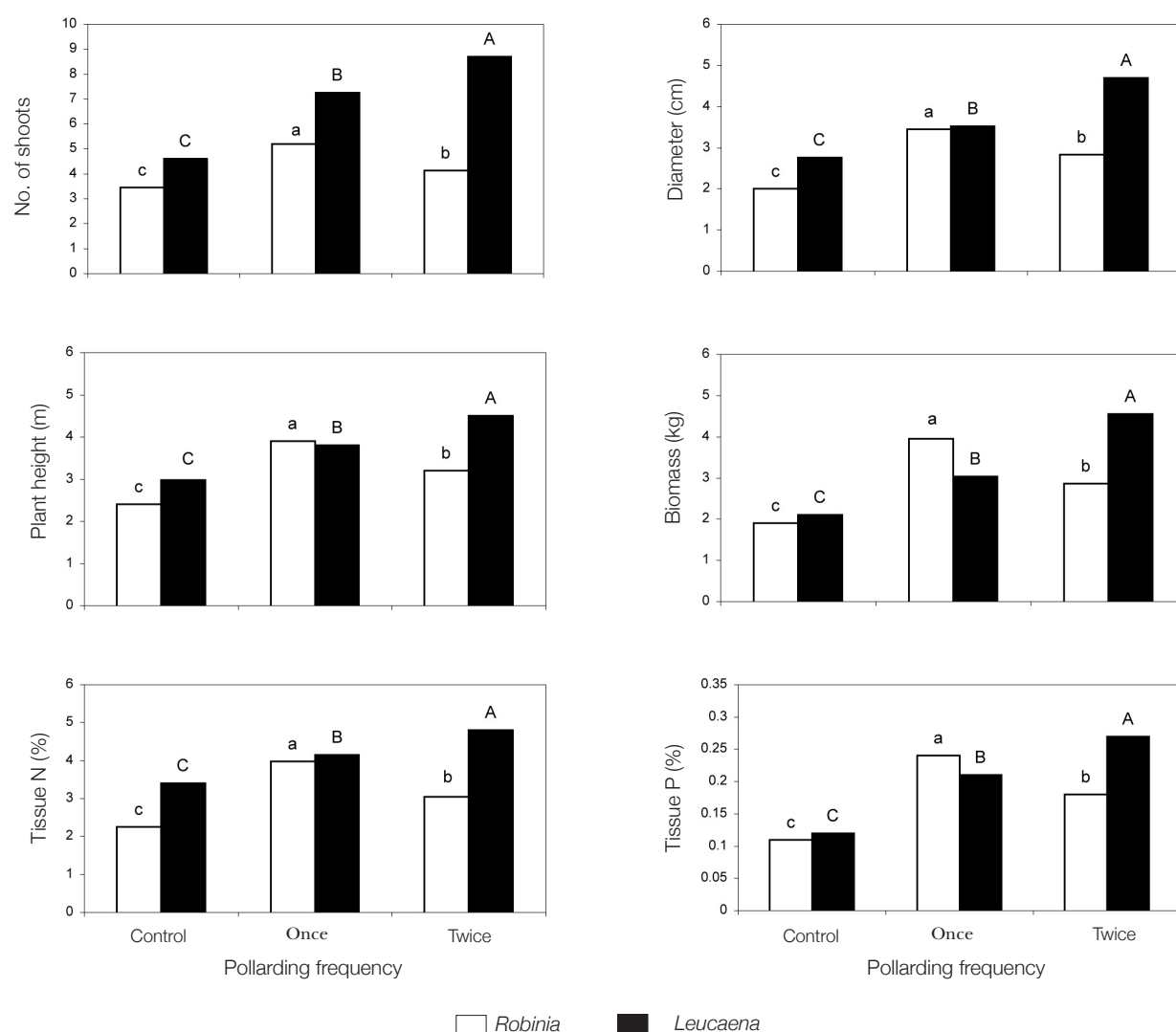
Both pollarding height and frequency had significant effects on the biomass production and nutrient concentration of *L. leucocephala* and *R. pseudoacacia*, but their interactions were not significant. For *L. leucocephala*, pollarding twice (every 3 months) at 15 cm yielded the greatest growth response and tissue N and P contents. For *R. pseudoacacia*, pollarding once after 6 months at a height of 45 cm yielded the highest biomass production and tissue N and P contents (Figures 2 and 3).

The physical properties of the soil were also significantly different under *L. leucocephala* and *R. pseudoacacia* (Table 1). Soil bulk densities were lower under both species (810 and 816 kg m<sup>-3</sup> for *L. leucocephala* and *R. pseudoacacia*

respectively) at the end of the experiment compared with the value prior to planting (901 kg m<sup>-3</sup>). Soil porosity was slightly higher under *L. leucocephala* and *R. pseudoacacia*, and infiltration rates were significantly greater than at the beginning of the experiment. Results of soil particle size distribution (texture) showed no differences in all fields. Soil chemical and nutrient properties were also significantly improved in the presence of the tree species (Table 2). Soil pH increased significantly under *L. leucocephala* and *R. pseudoacacia* (5.58 and 6.20 respectively compared with 4.92 prior to planting). Total soil organic matter and nitrogen under the tree species also increased significantly over the course of the experiment. Available potassium in the soil increased from an average of 212 ppm at the beginning of the experiment to 375 ppm



**Figure 2** Effects of pollarding height on *Leucaena leucocephala* and *Robinia pseudoacacia* growth responses. Bars with the same letter do not differ significantly ( $p < 0.05$ ).



**Figure 3** Effects of pollarding frequency on *L. leucocephala* and *R. pseudoacacia* growth responses. Bars with the same letter do not differ significantly ( $p < 0.05$ ).

**Table 1** Effects of *Leucaena leucocephala* and *Robinia pseudoacacia* on soil physical properties

Site	Bulk density (kg m <sup>-3</sup> )	Particle density (kg m <sup>-3</sup> )	Porosity (%)	Infiltration rate (cm min <sup>-1</sup> )	Particle size (%)		
					Sand	Silt	Clay
All field before planting	901 a	2220 b	64.22 b	0.43 c	41.20	26.40	30.40
<i>L. leucocephala</i>	810 b	2680 a	69.20 a	1.66 a	42.90	26.70	32.30
<i>R. pseudoacacia</i>	816 b	2605 a	67.45 ab	0.88 b	40.90	26.20	32.40
Open field at the end of the experiment	906	2225	63.40	0.56	41.00	26.20	30.80

Values within a column followed by the same letter do not differ significantly ( $p < 0.05$ ).

**Table 2** Effects of *L. leucocephala* and *R. pseudoacacia* on soil chemical properties and organic matter

Site	pH	Organic matter	Total N	P	K	NH <sub>4</sub> <sup>+</sup>	NO <sub>3</sub> <sup>-</sup>
		(%)					
All field before planting	4.92 c	2.72 c	0.23 c	10.60 a	212 c	102.22 a	62.00 a
<i>L. leucocephala</i>	5.85 b	4.50 a	0.38 a	10.85 a	375 a	108.40 a	64.60 a
<i>R. pseudoacacia</i>	6.20 a	3.85 b	0.33 b	11.20 a	304 b	104.85 a	63.40 a
Open field at the end of the experiment	4.78	2.50	0.22	10.50	202	101.40	61.80

Values within a column followed by the same letter do not differ significantly ( $p < 0.05$ ).

under *L. leucocephala* and 304 ppm under *R. pseudoacacia*. Available phosphorus, however, was not significantly different between the various treatments. Surprisingly, available ammonium and nitrate did not differ significantly between the soils although nitrogen availability in all soils was quite high, especially for ammonium.

## DISCUSSION

It is clear from the results that the two legume trees showed a significant ability to recover rapidly following pruning. Some tree species with resprouting capacity recover slowly following pruning while others recover rapidly by shifting carbohydrate reserves from basal tissues to resprouting stems (Garcia *et al.* 2001, Oppong *et al.* 2002, Wildy & Pate 2002). It has been reported that coppiced stumps of *L. leucocephala* and *Vitex negundo* showed an increasing trend in biomass production in the second harvest, and the yield per plant and on a per unit area basis were higher in coppiced stands (Tewari *et al.* 2004). In another report, black locust yielded more foliar biomass when pollarded at 50 or 100 cm than at 5 cm, with or without P fertilization (Burner *et al.* 2005). This is presumably due to a reduction in total storage carbohydrates available for regrowth (Magel *et al.* 1994, Larbi *et al.* 2005). Conversely, Duguma *et al.* (1988) found that increasing pruning frequency and decreasing pruning height increased the biomass, dry wood and nitrogen yield of *L. leucocephala*, *Gliricidia* and *Sesbania*. A lower pollarding height in *L. leucocephala* seedlings may stimulate greater growth response because of a greater concentration of storage carbohydrates in the basal portion of the stems which can be readily mobilized for regrowth. Similarly, *Gliricidia*

cuttings planted in the field tend to resprout at the base of the stem rather than at the distal end (personal observation). More work needs to be done to understand these contrasting growth responses.

Soil bulk densities were lower under both species compared with the fields prior to planting. This difference was probably due to the increase in soil organic matter under both species. The porosities of the soils were slightly higher under *L. leucocephala* and *R. pseudoacacia*, and infiltration rates were significantly greater than at the beginning of the experiment because of higher soil organic matter. Greater rooting activity of these tree species likely increased aggregate structure and macropore space (Young 1991).

The substantial increase in total nitrogen and available potassium is likely due to the inputs of nutrient-rich organic matter from these nitrogen-fixing species. On the other hand, nitrogen-fixing plants are known to reduce available soil P to the point where it can limit growth rates. Also, soils in this region are known to fix P (Wilkinson 1989). This may have masked organic P returns from the tree litter and pollarded biomass. The soils in this experiment had very high available nitrogen, especially ammonium, which may be a consequence of past fertilization as these soils had previously been used for tree seedling propagation. This may explain why the growth of these nitrogen-fixing trees failed to increase available soil nitrogen.

## CONCLUSIONS

Results indicate that both *L. leucocephala* and *R. pseudoacacia* are highly suitable for agroforestry and soil improvement in Iraq. Pollarding

frequency and height both significantly affected the growth rate and nutrient concentrations of resprouting stems of these species. For *L. leucocephala*, the optimal pollarding was every 3 months at 15 cm height. For *R. pseudoacacia*, the optimal pollarding was after 6 months at 45 cm height. Both species improved soil physical and chemical properties, organic matter and nutrient status. Management of these trees for soil improvement or in agroforestry systems should also take into consideration planting density to produce the desired levels of shade, soil cover and green manure, animal fodder, or wood products. They can also reduce the need for N and K fertilizers and pH adjustment.

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