ECOTROPICA 14: 27–35, 2008

GROWTH IN SAPLINGS OF *SCHINOPSIS BALANSAE* ENGL.

***C. Alzugaray[1], N.J. Carnevale[1, 2] & A.R. Salinas [1, 2]**

[1]Facultad de Ciencias Agrarias, [2]Consejo de Investigaciones de la Universidad Nacional de Rosario.
Campo Experimental Villarino. C.C.14. S2125ZAA. Zavalla. Santa Fe, Argentina.

Abstract. *Schinopsis balansae* is a characteristic tree of the Chaco province in northern Argentina, whose timber and tannin values are very high. At present it can be found in forests under intense exploitation. The object of this work was to evaluate the growth of young trees in two types of soil: typical Natraqualf (TN) and vertic Argiudoll (VA) at six, nine, and 12 months old. Leaf area (LA), total mass (TM), root mass (RM), stem mass (SM), and total root length (TRL) were evaluated. The allocation of biomass, the relative growth rates (RGR), the net assimilation rates (NAR), and the percentage increase of the total mass from the seed dry mass (=100%) were analyzed. The plant´s growth between the two types of soil was compared. *Schinopsis balansae* showed higher TM, RM, and SM ($p < 0.05$) in VA at nine months old. At 12 months old, there were higher LA and SM ($p < 0.01$) in VA. Allocation of biomass tended to balance at 1:1 (SM:RM) while the plants were becoming older in both types of soil. RGR, NAR, and the increase in TM at nine months old showed a peak growth of 27 $mg.g^{-1} day^{-1}$; 0.33 $mg.cm^{-2} day^{-1}$ and 23 100% in VA soil ($p < 0.05$). *Schinopsis balansae* positively responded to edaphic differences and can be employed to reforest degraded forests. *Accepted 27 October 2007.*

Key words: *endemic tree*, *growth analysis*, *saplings*.

INTRODUCTION

Schinopsis balansae (“quebracho colorado”) is a tree of the Anacardiaceae family, and the genus *Schinopsis* is endemic to South America. The genus includes seven species, four of them being found in Argentina, two species of which are of economic significance (Meyer & Barkley 1973). Of the latter, *S. balansae* is in the Forest Wedge of the Santa Fe Province (Ragonese & Covas 1940, Cabrera & Willink 1980). This region is characterized by its large woody areas interrupted by grassy clearings, “abras”, and wetlands. These forests are not homogeneous, with three main types being related to topographical and latitudinal gradients: the “bosque chaqueño”, the “quebrachal” of *S. balansae*, and the “algarrobales” of *Prosopis nigra* Griseb. (Lewis & Pire 1981). Additionally, these forests show variations in flowering composition due to a thermal and hydrological gradient (Lewis 1991). Due to exploitation, forests in this region have suffered serious damage. Only 400 000 of the 5 900 000 ha surveyed in the 1915 forestry census still remain (Carnevale *et al.* 2006). *Schinopsis balansae* was the raw material for the production of tannin extract by the “La Forestal” company up to 1962. Moreover, “quebracho colorado” wood is still being taken for firewood and charcoal. Nowadays the “quebrachal” has disappeared from some places and it is highly fragmented or underused (Alzugaray *et al.* 2005).

The “quebracho colorado” tree can be 24 m high and its trunk is sometimes wider than a meter. It is a heliophyte species, described by Muñoz (2000) as a polygamous-dioecious species growing from seed. The wood of this tree is very heavy and hard, with a specific weight of 1.2 $kg.dm^{-3}$. Its main use is to obtain quebracho extract, which contains 63% of pure tannin (Solá 1942, Streit & Fengel l994). Considered the national forestry tree, it is the pioneer native species of forestry development in the country. Valentini (1955, 1960) and Barret (1998) have summarized the research done in the country up to the present, principally focusing on the basic rules of management for a successful crop in pure or mixed plantations with exotic species, with the aim of obtaining a higher yield through suitable management. Patiño *et al.* (1994) analyzed timber yield in test plots of *S. balansae* planted in Chaco province in 1951 and 1963. They concluded that the yield can be notably different according to the quality of the sites. Wenzel & Ham-

---

e-mail: calzugar@unr.edu.ar

pel (1998) analyzed regeneration in natural populations in the humid Chaco. The variables used to analyze the growth, either in plantations or in natural populations, have been growth rings, height, and diameter at breast height. Growth analysis has not been used in any of these cases. Barberis (1998) also analyzed the distribution and regeneration of woody species, including *Schinopsis balansae*, in relation to environmental heterogeneity, but in terms of emergence and seedling recruitment. As regards worldwide growth analysis, the literature shows that arboreal species have been studied in temperate-cold (Reich *et al.* l998) or tropical climates (Poorter 1999, Barberis 2001) but only in the seedling phase. This methodology has not been used with species in the "chaquenian" region. *Schinopsis balansae* is a slow-growing species in the first stages of its life and it also positively responds to soil quality. The aim of this work was to evaluate the growth of *Schinopsis balansae* saplings of between six months and one year old in two types of soil: vertic Argiudoll and typical Natraqualf. This would allow us to know the species' potential when planning reforestation in degraded forests or planting in commercial greenhouses.

MATERIALS AND METHODS

Schinopsis balansae samaras were collected in the Experimental Station of the Agriculture Ministry "Dr. Tito Livio Coppa" in Las Gamas, Vera City, Santa Fe Province, Argentina (29°30´S, 60°45´W) in March 2002. They were sown in plastic pots to obtain 200 saplings, 100 of which were sown in soil from Vera: typical Natraqualf (Mussetti & Alconchel 1986) and 100 in Zavalla soil: vertic Argiudoll (Busso & Ausilio 1989). In spite of the fact that the present distribution area of *Schinopsis balansae* has been reduced, this species was originally distributed in a wide variety of soils (Espino *et al.* 1983, Marino & Pensiero 2003), Argiudolls, Natraqualfs, and Ochraqualfs among them. The main characteristics of the soils used for the tests are summarized in Table 1. The soil from Zavalla was taken from horizon A in plots that have never been used for agriculture or cattle breeding purposes, located in "Campo Experimental Villarino, Facultad de Ciencias Agrarias, Universidad Nacional de Rosario". The soil from Vera was taken from the A2 and B21 horizons in plots selected from the forest, situated in the "Estación Experimental" of Las Gamas.

Ten composite soil samples were taken from A2 (0–10 cm) and B21 (10–25 cm) in NT and from A (0–25cm) in VA. The following measurements were made in each sample: organic matter according to Walkley and Black (Nelson & Sommers 1996), assimilable P (Bray & Kurtz 1945), total N after Kjeldahl, pH (1:2.5 relation), Na^+ (flame photometry), Ca^{++}, Mg^{++}, and K^+ were determined by humid ash (Jackson 1958). Variables from both types of soil were compared using Student's t-test.

The samaras were sown in April 2002 and saplings were kept in containers that were 15 cm in diameter and 25 cm high. They were assessed at six, nine, and 12 months old. Data from 10 plants of homogeneous characteristics from each type of soil were taken in each assessment. Plants were kept in similar conditions as regards light, watering, and temperature. Leaf area (LA), total root length (TRL), total plant mass (TPM), root mass (RM), and stem mass (SM) were evaluated. The LA was determined by means of a leaf area meter "L1-3100-Area Meter". Roots were washed, dried, and placed on paper to obtain TRL. Plants

TABLE 1: Main characteristics of typical Natraqualf (TN) and vertic Argiudoll (VA) soils.

	Typical Natraqualf		Vertic Argiudoll
Horizon	A2	B21	A
Thickness (cm)	0-10	10-25	0-25
Clay < 2 (%)	18	28	25
Silt 2-50 (%)	79.5	69.5	62.7
Sand (%)	1.88	1.92	12.1
Base saturation S/T (%)	98.8	93.9	82
Base sum (S) cmol.kg^{-1}	17.8	24.7	18.3
Exchange cationic capacity (ECC)	18	26.3	21.9

TABLE 2: Organic matter (%), Total Nitrogen (%), Phosphorus, (ppm), pH and cations (meq/100g) of typical Natraqualf (TN) and vertic Argiudoll (VA) soils.

	Typical Natraqualf		Vertic Argiudoll
Horizon	A2	B21	A
Thickness (cm)	0- 10	10- 25	0- 25
Organic Matter (%)	7.14	4.1	3.7
Total Nitrogen (%)	0.33	0.21	0.15
Phosphorus (ppm)	42.26	11.26	63
Sodium ($cmol.kg^{-1}$)	2.45	4.45	0.38
Calcium ($cmol.kg^{-1}$)	14.02	17.31	13.01
Potassium ($cmol.kg^{-1}$)	1.62	1.67	1.83
Magnesium ($cmol.kg^{-1}$)	5.1	7.12	1.9
pH	6.4	7.2	5.7

were then scanned at real scale, and acetate paper with a grid (1 x 1 cm) was placed on each of the images, according to the total length of the roots to be measured (Tennant 1975). Dry matter was determined by separating the stem from the root and by drying them in a stove at 70°C until a constant weight was reached, then they were weighed on an analytical balance. The following variables were derived from the primary data: root mass ratio (RMR = RM/TPM), stem mass ratio (SMR = SM/TPM), leaf area ratio (LAR = LA/TPM), root length ratio (RLR = TRL/TPM), and specific root length ratio (SRLR = TRL/RM) (Ashton *et al.* 1995, Poorter & Garnier 1996, 1999; Poorter 1999). Relative growth rates (RGR: biomass growth per unit plant biomass, in $mg.g^{-1}day^{-1}$) were calculated following the Causton & Venus formulae (1981), and net assimilation rates (NAR: biomass growth per unit leaf area, in $mg.cm^{-2}day^{-1}$) were calculated according to Hunt (1978).

All dependent variables were transformed to natural logarithms (ln) to compute RGR and NAR. RGR and NAR were compared following the methodology of Poorter & Lewis (1986). Data were analyzed as a factorial 2 x 2 (2 plant ages x 2 types of soil). Finally, the dry mass of individual seeds was related to the total plant mass (TPM) of saplings at six, nine, and 12 months old. The percentage increase of TPM in saplings from the seed dry mass (= 100 %) was computed (Parolin 2001).

The Student's t-test or the Wilcoxon test for comparing growth responses in both types of soil was done at the 5% probability level ($p < 0.05$) at each step of the assessment (Aronson *et al.* 1992, Ribichich l996).

RESULTS

Table 2 shows the median values of organic matter, assimilable P, total N, pH, Na^+, Ca^{++}, Mg^{++}, and K^+ from each soil.

The six-month data from variables LA, TPM, RM, SM, and TRL did not show any statistically significant differences between both treatments (Fig. 1). Nine-month-old plants showed significant differences ($p < 0.05$) in TPM, RM, and SM, with higher values being observed in plants growing in VA soil. LA showed a marginally significant difference ($p < 0.067$), with a higher average value in plants growing in VA soil. This advantage in dry mass and in LA was evident at 12 months old, with greater foliage area (LA) and a higher SM ($p < 0.01$) in plants growing in VA soil (Fig. 1).

With regard to biomass distribution, plants in both soils started from a proportion of 3:1 of SM:RM at six months old, and then they showed a decrease of SM and an increase of RM over time, favoring the development of the root system. RMR, SMR, LAR, RLR, and SRLR were not significantly different for both types of soil in six-month-old plants. Plants in TN soil developed a larger photosynthetic surface in TPM units at nine months old. This was shown in higher values of LAR ($p < 0.01$) while RMR, SMR, RLR and SRLR did not show any statistically significant differences. Twelve-month-old plants showed significant differences in RMR and SMR, with the higher value of SMR in VA soil ($p < 0.05$). The greatest RMR in TN soil ($p < 0.02$) contrasted with the lesser SRLR ($p < 0.05$) (Fig. 2). RGR and NAR showed a peak in nine month-old plants, with sig-

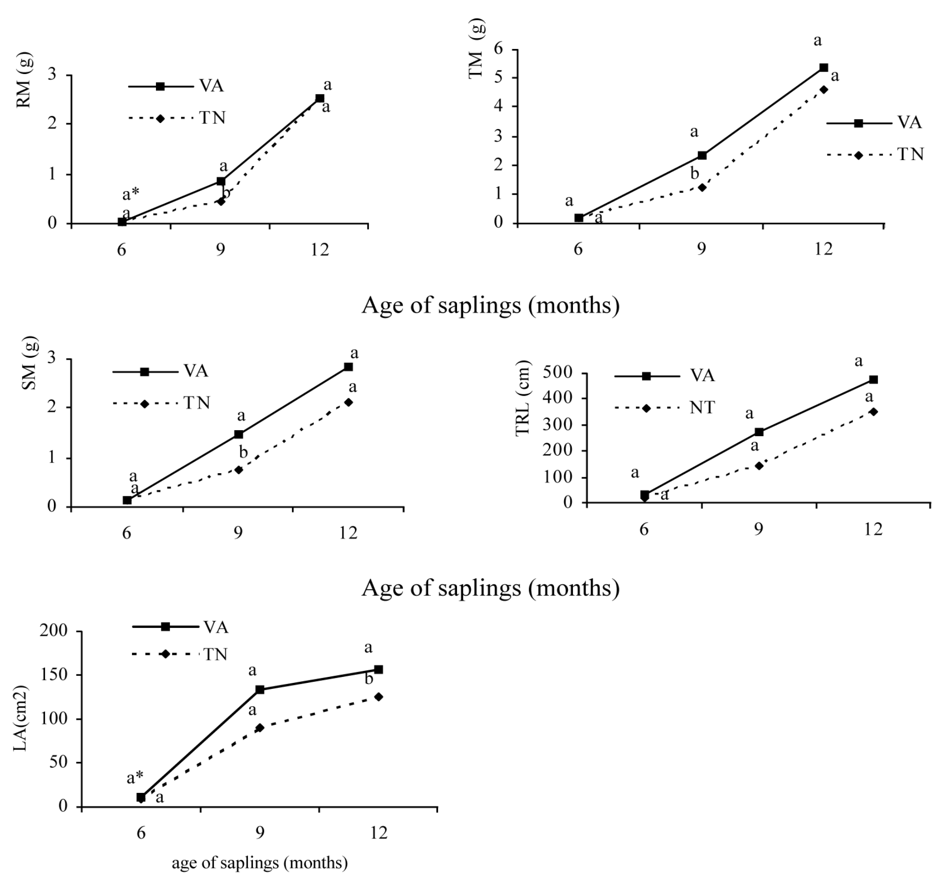

FIG. 1: Leaf area (LA), total root length (TRL), root mass (RM), stem mass (SM), and total mass (TM) of *Schinopsis balansae* Engl. plants at six, nine, and 12 months old in two types of soil: typical Natraqualf (TN) and vertic Argiudoll (VA). *Same letters indicate that media are not significantly different at $p < 0.05$ (Student's t-test).

nificant differences ($p < 0.023$) in VA soil (Fig. 3). There were no statistically significant differences either at six or 12 months for RGR, or 12 months for NAR. Dry mass increase can be seen in Figure 4, showing significant statistical differences ($p < 0.01$) in nine-month-old plants.

DISCUSSION

Typical Natraqualf soils show sodium alkalinity in one of the horizons or throughout the whole soil profile, so proportionately less P is available than in soils with 5.5 to 6 pH. In addition, they retain little water on the surface due to their high silt levels (79.5 and 69.5% in the horizons A2 and B21). Considering that the content of silt and clays when added together is around 95 to 97%, the edaphic micro-environment is extremely compact, thus making it difficult for the roots to enter the soil. It has been shown that soil composition affects root development and that root systems are the main deposits of dry matter with regard to biomass distribution and annual weight increase, depending on ecological factors and species (Vilche *et al.* 2000, Le Goff & Ottorini 2001). In forest species in fine-textured soils, roots are shorter and more branched than in coarse-textured ones (Glinski & Lipiec l990). At six months old, *S. balansae* did not show any significant growing differences, or any differences due to the type of soil. *Schinopsis balansae* stored about 24 to 54% of biomass in the roots depending on the age of the plants and the soil, tending to balance the distribution of the biomass at a 1:1 (SM:RM) ratio while the plants increased their age and size in both types of soil. Otherwise, according to the results obtained in this research, the distribution of the biomass seemed to respond to edaphic differences in different fractions of *S. balansae* at 12 months old. The greater quantity of root biomass contrasting with its lesser length in Natraqualf soil would seem to show that the root system in this type of soil is less expansive yet heavier per unit of total dry mass. This is explained by the greater resistance of Natraqualf soil to penetration, which affects both root architecture and development. Furthermore, small differences in clay content (6 or 7%) may considerably limit the plant's growth because of less water circulation and the hardness of the soil, consequently in-

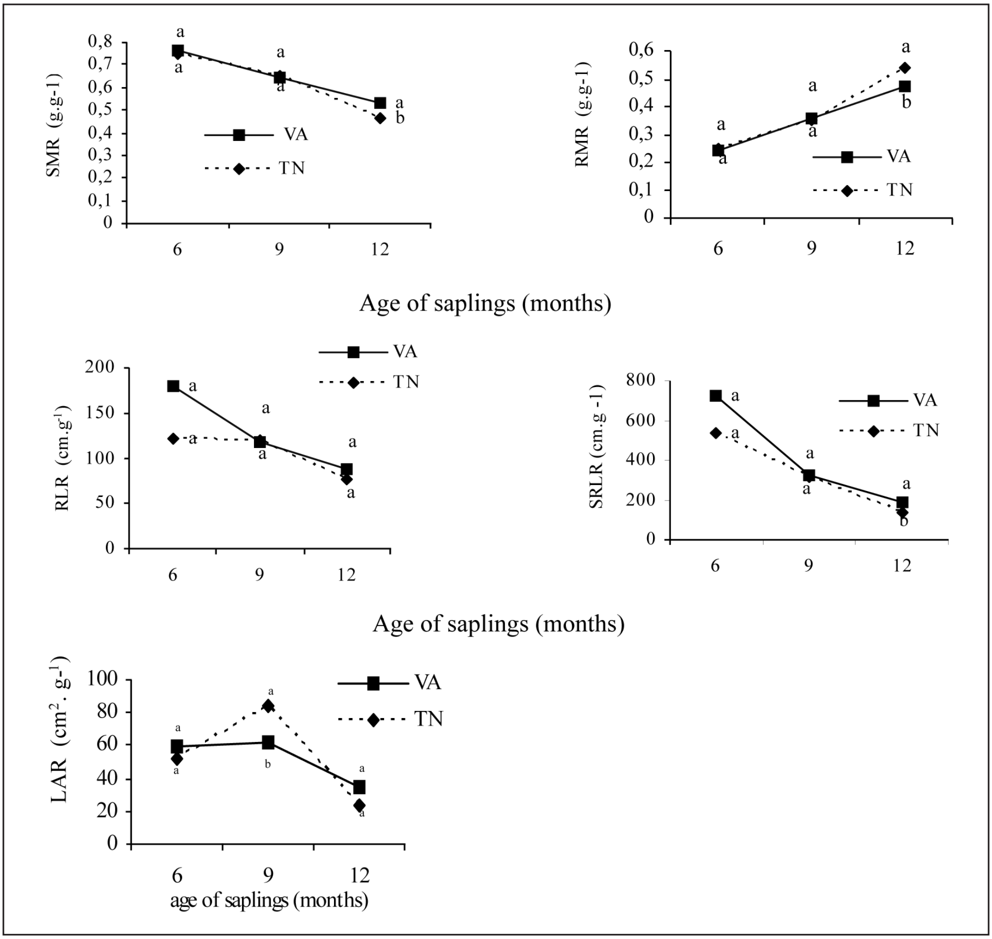

FIG. 2: Root mass ratio (RMR), stem mass ratio (SMR), leaf area ratio (LAR), root length ratio (RLR), and specific root length ratio (SRLR) in *Schinopsis balansae* Engl. plants at six, nine, and 12 months old in two types of soil: typical Natraqualf (TN) and vertic Argiudoll (VA). *Same letters indicate that media are not significantly different at $p < 0.05$ (Student's t-test).

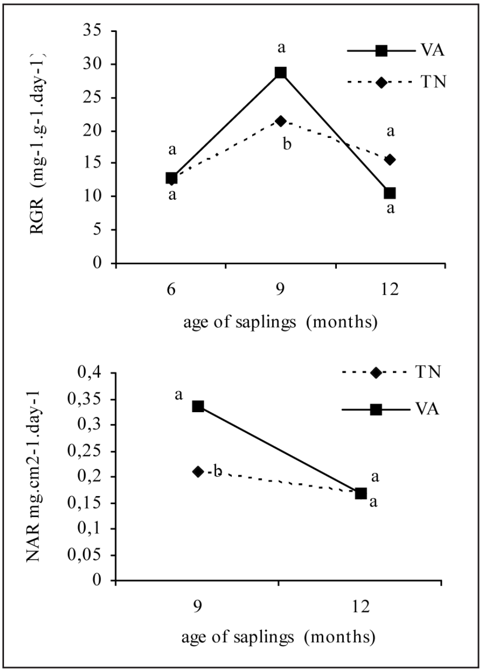

FIG. 3: Relative growth rate (RGR) and net assimilation rate (NAR) in *Schinopsis balansae* Engl. Plants, evaluated in three and two measurements respectively, in two types of soil: typical Natraqualf (TN) and vertic Argiudoll (VA). *Same letters indicate that media are not significantly different at $p < 0.05$ (Student's t-test).

creasing the salt effect (Patiño *et al.* 1994). Besides having a better physical condition than Natraqualf soils, the vertic Argiudoll soils of Zavalla have a high supply of assimilable P (an average of 63 ppm), compared with 42.26 and 11.26 ppm respectively in samples of TN in the first 25 cm of soil. This variable shows a significant difference ($p < 0.001$) in both soils. It has been demonstrated than young *Schinopsis balansae* trees respond to P supply in the top 10 cm of soil (Prause & Marinich 2001).

Differences arose in *Schinopsis balansae* saplings during the first year, in correspondence with the soil characteristics mentioned, and later greater differences in biomass and growth rings could be determined. Twelve-month-old plants in Argiudoll soil with higher values of LA, SMR, and SRLR support this. Patiño *et al.* (1994) stated that *S. balansae* is able to live in limiting environments, showing differing reactions to site quality and yielding very different timber volumes per unit of area.

According to various authors, *Schinopsis balansae* is considered a slow-growing pioneer heliophyte species which thrives in a succession ecosystem (Lewis 1991, Wenzel & Hampel 1998, Bercovich 2000, Hampel 2000). Therefore, if sustainability in the long term of these forests were put forward, it would be necessary to know the elements that affect regeneration, as in the case of RGR of these species among others. *Schinopsis balansae* grew at a rate of 13 mg.g^{-1} day^{-1} in both types of soil, starting with the seed dry weight as the first assessment, up to six months old when the first plant harvest took place. Then it showed a peak of growth at nine months old, at 20 and 27 mg.g^{-1} day^{-1} in TN and VA soils respectively. This growth curve is the typical curve in some higher plants, at least in the early stages, from seed germination to sapling stage (Salisbury & Ross 2000). The growth rate for many plants is quite complex, varing from species to species or with changes in the environment (Hopkins 1995). In this case, the peak at nine months illustrates the adaptation of *Schinopsis balansae* to different soils in the period of maximum growth. Other authors consider *Schinopsis balansae* to be a "tolerant" species (Patiño *et al.* 1994, Barret 1998). RGR data of *Cecropia* sp. Loefl, a pioneer species of Costa Rican tropical forest, showed an increase of 23 mg.g^{-1}day^{-1} between the fourth and sixth weeks of life (Poorter 1999). *Simaruba amara* L., a pioneer species of high growth rates found in the tropical forest of Barro Colorado Island, Panamá, showed an seedling RGR of between 10 and 15 mg.g^{-1}day^{-1} between the first weeks and one year. Its seed dry weight is 0.38 g (Barberis 2001). Even though data from other tropical species cannot be compared, they are useful as reference values of pioneer species in other ecosystems. *Schinopsis balansae* showed a rather high RGR, taking into consideration that its seed dry mass is 0,01 g. There are a series of variables, like the small size of the seeds, the shade intolerance, the endurance of dry conditions and barren soil, which are associated with the ecological niche or habitat of pioneer species (Poorter & Garnier 1999). We stated initially that the growth of *S. balansae* young seedlings responded poorly to better edaphic conditions, but our results showed a contrasting positive response before the year was over. Poorter (1999) and Barberis (2001) showed

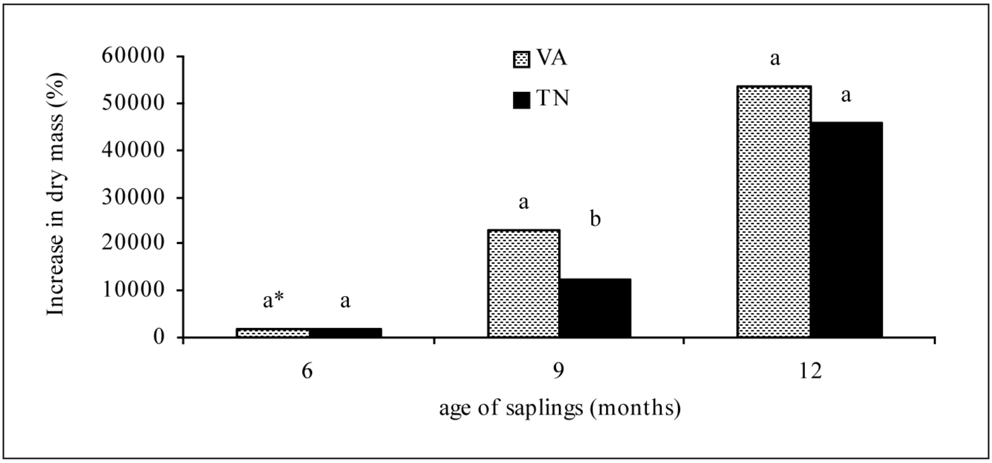

FIG. 4: Increase in dry mass (%) of *Schinopsis balansae* Engl. young plants from seed dry mass (= 100%) at six, nine, and 12 months old. *Same letters indicate that media are not significantly different at $p < 0.05$ (Student's t-test).

the existence of a range of responses in species that can be grouped from pioneer to shade-tolerant plants.

In pioneer species, the small size of the seeds is a common feature. *Senna reticulata* (Willd.) Irwin et Barn is a tree of the central Amazonian forest whose seed dry mass is 0.01 g and which at five months old has increased its weight by up to 19 300%. *Vitex cymosa* Bertero ex Spreng., with a seed mass of 0.2 g, increases its weight by up to 731.7% in five months. Both species can be found in a forest area rich in nutrients but would be at the extreme points of a gradient of pioneer species (Parolin 2001). *Schinopsis balansae* increased its dry mass by 23 000% and 12 200 % at nine months old in Argiudoll and Natraqualf soils respectively.

Schinopsis balansae grows spontaneously in poor soils, and only hardy species like "quebracho" develop in these soils. Nevertheless, *S. balansae* responds to better soil conditions, improving its productivity, at least in the sapling stage. Our results support the classification of *Schinopsis balansae* as a pioneer species in the "quebrachal", very efficient in the use of resources and growing rapidly in its optimum environment.

CONCLUSION

According to the results obtained in this work, it can be stated that *S. balansae* is a species of quite rapid growth, at least during the first year of sapling growth, and that it significantly responds to favourable edaphic conditions. Furthermore, considering the high value of its timber and tannin, *Schinopsis balansae* is a species that should be used to reforest degraded "quebrachales" and other areas devoted to forestry in monoculture or in mixed cropping systems.

ACKNOWLEDGMENTS

The authors are grateful to Ing. Luis Schaumburg, Mr. Rodolfo Comuzzi, and Mr. Sergio Acosta of the Agriculture Ministry "Dr. Tito Livio Coppa", Santa Fe Province, Argentina for their logistic support, and to Dr. Ignacio Barberis for his suggestions.

REFERENCES

Alzugaray, C., Carnevale, N.J., & N. Di Leo. 2005. Mapa de clasificación de unidades de cobertura de vegetación en la Cuña Boscosa santafesina. III Congreso Nacional sobre manejo de pastizales naturales: 55.

Aronson, J., Ovalle, C., & J. Avendaño. 1992. Early growth rate and nitrogen fixation potential in forty-four legume species grown in an acid and a neutral soil from central Chile. Forest Ecology and Management 47: 225–244.

Ashton, P.M., Gunatilleke, C.V.S., & I.A.U.N. Gunatilleke. 1995. Seedling survival and growth of four *Shorea* species in a Sri Lankan rainforest. Journal of Tropical Ecology 11: 263–279.

Barberis, I.M. 1998. Distribución y regeneración de especies leñosas en relación con la heterogeneidad ambiental en un bosque de *Schinopsis balansae* del sur del Chaco Oriental. Tesis de posgrado en la carrera de Magister Scientiae en Recursos Naturales. Universidad de Buenos Aires Argentina.

Barberis, I.M. 2001. Above and belowground competition for seedlings in a Panamanian moist forest. PhD thesis, University of Cambridge, Cambridge.

Barret, W. 1998. Antecedentes y situación actual del cultivo del Quebracho Colorado (*Schinopsis balansae*) en el Chaco Argentino. SAGPyA Forestal 7: 7–18.

Bercovich, N. 2000. Evolución y situación actual del complejo Forestal en Argentina. División de desarrollo productivo y empresarial de la Comisión Económica para América Latina y el Caribe. Ed. Centro Internacional de Investigaciones para el desarrollo (CIID/IDRC).

Busso, A., & A. Ausilio. 1989. Mapa de suelos del Campo experimental "José V. Villarino". Ed. Fac. de Ciencias Agrarias. Universidad Nacional de Rosario. Publicación Técnica Nº 5.

Bray, R., & L.T. Kurtz. 1945. Determination of total organic and available forms of phosphorus in soils. Soil Sci. 59: 39–42.

Cabrera, A.L., & A. Willink. 1980. Biogeografía de América Latina. Monografías científicas, Serie Biológica 13. Secretaría General de la O.E.A., Washington, D.C.

Carnevale, N.J., Alzugaray, C., & N. Di Leo. 2006. Análisis de la deforestación en la Cuña Boscosa Santafesina. XXII Reunión Argentina de Ecología: 253.

Causton, D.R., & J.C. Venus. 1981. The biometry of plant growth. Edward Arnold, London.

Espino, L., Severo, M.A., & M. Sabatier. 1983. Mapa de suelos de la Provincia de Santa Fe. Ed. INTA. MAG. Argentina. Tomo II.

Glinski, J., & J. Lipiec. 1990. Soil Physical Conditions and Plant Roots. Institute of Agrophysics, Polish Academy of Sciences.

Hampel, H. 2000. Estudio de la estructura, dinámica y manejo de bosques del Chaco Húmedo Argentino. Conjunto de artículos. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). Eschborn, Germany.

Hopkins, W.G. 1995. Introduction to plant physiology. John Wiley & Sons, USA.

Hunt, R. 1978. Plant growth analysis. Edward Arnold, London.

Jackson, M.L. 1958. Soil Chemical Analysis. Constable, London.

Le Goff, N., & J.M. Ottorini. 2001. Root biomass and biomass increment in a beech (*Fagus sylvatica* L.) stand in North-East France. Annals of Forest Science 58: 1–13.

Lewis, J.P. 1991.Three levels of floristical variation in the forest of Chaco, Argentina. Journal of Vegetation Science 2: 125–130.

Lewis, J.P., & E.F. Pire. 1981. Reseña sobre la vegetación del Chaco santafesino. Instituto Nacional de Tecnología Agropecuaria. Serie Fitogeográfica 18. Ed. Centro de investigaciones de Recursos Naturales. INTA. Buenos Aires.

Marino, G.D., & J.F. Pensiero. 2003. Heterogeneidad florística y estructural de los bosques de *Schinopsis balansae* (Anacardiaceae) en el sur del Chaco húmedo. Darwiniana 41 (1-4): 17–28.

Meyer, T., & F. Barkley. 1973. Revisión del género *Schinopsis* (Anacardiaceae). Lilloa 33 (11): 207–257.

Muñoz, J.D.D. 2000. Flora Fanerógama Argentina, Fascículo 65. *ProFlora*. CONICET, Buenos Aires.

Mussetti, M., & D. Alconchel. 1986. Mapa de suelos del centro operativo Dr. Tito Livio Coppa, Las Gamas, Dpto. Vera, Santa Fe. Dirección General de Extensión e Investigaciones Agropecuarias, Santa Fe.

Nelson, D.W., & L.E. Sommers. 1996. Methods of Soil Analysis. Part 3. Chemical Methods, SSSA Book Series Nº 5, SSSA-ASA. Madison, Wisconsin, USA.

Parolin, P. 2001. Seed germination and early establishment of 12 tree species from nutrient-rich and nutrient-poor Central Amazonian floodplains. Aquatic Botany 70: 89–103.

Patiño, C.A., Reboratti, H.J., & P. Del Valle. 1994. Rendimiento maderable de plantaciones de quebracho colorado (*Schinopsis balansae*) en suelos arcillosos del Chaco Oriental. RIA. INTA. 25 (2): 115–127.

Poorter, H. 1999. Growth responses of 15 rain forest tree species to a light gradient: the relative importance of morphological and physiological traits. Functional Ecology 13: 396–410.

Poorter, H., & E. Garnier. 1999. Ecological significance of inherent variation in relative growth rate and its components. Pp. 81–120 *in* Handbook of functional plant ecology. Marcel Dekker, New York, USA.

Poorter, H., & E. Garnier. 1996. Plant growth analysis: an evaluation of experimental design and computational methods. Journal of Experimental Botany 47 (302): 1343–1351.

Prause, J., & M.J. Marinich. 2001. Evaluación de la actividad radical en *Schinopsis balansae* Engl. Empleando. Publicación técnica de la Facultad de Ciencias Agrarias. Ed. Universidad del Nordeste.

Ragonese, A., & G. Covas. 1940. La distribución de los quebrachales en la provincia de Santa Fe. Rev. Argentina de Agronomía. 7 (3): 176–184.

Reich, P.B., Tjoelker, M.G., Walters, M.B., Vanderklein, D.W., & C. Buschena. 1998. Close association of RGR, leaf and root morphology, seed mass and shade tolerance in seedlings of nine boreal tree species grown in high and low light. Functional Ecology 12: 327–338.

Ribichich, A.M. 1996. *Celtis tala* Planchon (Ulmaceae) seedling establishment on contrasting soils and microdisturbances: A greenhouse trial concerning adults´field distribution pattern. Flora 191: 321–327.

Salisbury, F.B., & C.W. Ross. 2000. Fisiología de las plantas. Ed. Thompson Editores. España.

Solá, W. 1942. Arboles y arbustos de Córdoba. Ed. Celtis, Buenos Aires.

Streit, W., & D. Fengel. 1994. Purified tannins from Quebracho colorado. Phytochemistry 36 (2): 481–484.

Tennant, D. 1975. A test of a modified line intercept method of estimating root length. Journal of Ecology 63: 995–1103.

Valentini, J.A. 1955. Reforestación con quebracho colorado. M.A.G.N. Administración Nacional de Bosques: Dirección Nacional de Forestación y Reforestación. Hoja de divulgación Nº 9, Buenos Aires.

Valentini, J.A. 1960. La reforestación con quebracho colorado y algunas normas silvícolas relacionadas con su aprovechamiento racional. Bomplandia 1(1): 51–69.

Vilche, M.S., Alzugaray, C., & S. Montico. 2000. Relación entre la heterogeneidad de un suelo y la distribución de las raíces. Rev. Facultad de Agronomía 20 (1): 75–81.

Wenzel, M., & H. Hampel. 1998. Regeneración de las principales especies arbóreas del Chaco húmedo argentino. Quebracho 6: 5–18.