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# THE *EUCALYPTUS* AND THE *LEGUMINOSAE*
## Part 01: *Acacia mearnsii*


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**June 2008**

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## INTRODUCTION

The *Leguminosae* comprise one of the largest botanical families, widely distributed all over our planet. All family has about 18,000 species, a large part of them having commercial value or some sort of usefulness for man or to the animals. The *Leguminosae* are characterized by having fruits in the form of legume fruit or fava bean. For this reason they are also known as *Fabaceae*. At least three subfamilies are accepted in the group: *Papilionoideae*, *Faboideae* and *Mimosoideae*.

The *Leguminosae* vary from small-sized plants, as the agricultural cultures of soybeans, beans, peas, alfalfa, lentil and chickpea, to the tree-sized plants, as the acacias (*Acacia mangium* and *Acacia mearnsii*) and bracatinga (*Mimosa scabrella*). All these latter trees belong to *Mimosoideae* or *Mimosaceae* subfamily. Furthermore, there is a large amount of shrubby vegetables in the family, as the mesquites (*Prosopis spp*.), aromos (*Acacia dealbata* and others), cassias, crotalarias (Desert Senna, sometimes also called "rattlepod") and many other species very well known in Latin America.

Almost all species of *Leguminosae* present a radicular symbiosis with species of bacteria known as *Rhizobia*. These bacteria are air nitrogen fixing and therefore they aggregate a fantastic quality to the agricultural cultures. Many *Leguminosae* are used as source of nitrogen green fertilization, because the plants of *Leguminosae* receive nitrogen from these bacteria in the form of ions, incorporating it into their parts, such as leaves, flowers, barks, etc. Thus they are enriched with this important nutrient. The agricultural and economic consequences of this symbiosis are remarkable. The fruits and seeds of these *Leguminosae* are very protein and amino acid rich, while the cultures require little or no nitrogen fertilization at all.

The plants of *Leguminosae* also exhibit a rare aesthetic beauty, with their intense and beautiful flowerings, considerably sought by the bees and melliferous wasps. Several of these plants are used in backyard and landscape gardening.

There are also several *Leguminosae* trees that are native from Brazil, capable of producing high quality woods and thus contributing to the economic regional growth: Brazil-wood (Bahia jacaranda), ironwood, jacaranda, guapuruvu *(Schizolobium parahyba)*, sucupira *(Pterodon emarginatus)*, angelim (group of plants as *Andira anthelmia, Andira vermifuga, Vataireopsis araroba*), sibipiruna (*Caesalpinia peltophoroides*), canafistula (*Cassia fistula*), arariba (*Centrolobium tomentosum*), barba-timao (*Stryphnodendron adstringens*), etc.

Among the *Leguminosae* showing strong silvicultural interest for wood production in Brazil, the species *Acacia mearnsii* (black wattle), *Acacia mangium* and *Mimosa scabrella* distinguish themselves. The three of them are already being planted in forest stands and thus supplying wood to some Brazilian regions. The bracatinga *(Mimosa scabrella)* and the black wattle are more abundant in the south of the country (States of Parana, Rio Grande do Sul and Santa Catarina). As regard to *Acacia mangium*, its potential is being evaluated for several regions all over the country. The latter is a commercial tropical high-rusticity species with rapid wood generation for several industrial and energetic uses.

In these two **Eucalyptus Online Book** chapters called **"The *Eucalyptus* and the *Leguminosae*"** we will discuss the complementarity for growing planted forests of *Eucalyptus* and several of these *Leguminosae*. We think that much better than to compare *Eucalyptus* to

*Leguminosae*, aiming to choose one or the other of the genera involved, the ideal procedure is to find solutions to integrate them through science and new forest technologies, because there are numerous advantages involved in this practice of planting both of them, rather than only one. The main reasons are of environmental, social and economic nature i.e. strongly focussed on forest sustainability.

Although up to this moment the *Eucalyptus* present a much more advanced stage of genetic forest improvement, thus showing much higher productivity, these *Leguminosae* offer a wide field for productivity gains in terms of quantity and quality of wood and other associated products (tannin, carbon, charcoal, etc.). The present acacia and bracatinga wood productivity in Brazil is similar to the growth rates achieved with *Eucalyptus* trees along the seventies. At that time, *Eucalyptus* hybridization and cloning were just at their initial stage. Most of the seedlings were made with seeds from seed producing areas and some of them with seeds from seed orchards, which were not yet clonal. This means that in this period of 30 to 40 years of *Eucalyptus* plantation forestry we were able to grow from a productivity of 20 to 25 $m^3$/ha.year to about 40 to 55. I wonder whether we would not have the same competence to reach such gains with regard to our friend's acacias and bracatinga as well. These three forest species (*Acacia mangium*, *Acacia mearnsii* and *Mimosa scabrella*) present a potential for much higher growth rates than the present ones. It is also possible to improve the form of the trees and to solve chronic forest phytopathology problems, as e.g. the black wattle gummosis. For this reason, it is the synergy between *Eucalyptus* and *Leguminosae* that should be aimed at, not the competition between these forest species.

I am surprised at the concern shown by some Brazilian forestry business people with regard to *Acacia mangium*, which is being intensively planted in Indonesia for pulp production. I notice that they are looking at the competition between *Eucalyptus* and *Acacia*, rather than at the potential of utilization of these trees here in Brazil as well. It is a matter to become aware of, to be researched and to be better worked on.

There is in Brazil at present an enormous knowledge and competence on forest and industrial *Eucalyptus* technologies. Most probably we are world leaders in this respect. However, this present situation of comfort and prominence of ours was very different from this state of the art 30 to 40 years ago. We have been capable of aggregating much knowledge and much technology to the *Eucalyptus* plantation forestry. We have even been so competent as to raise the *Eucalyptus* pulp to the position of one of the most demanded on the world pulp markets, while its participation on them was very small in the sixties. Therefore, I believe that we are able to be equally successful as far as new technologies to be developed and to be applied to the acacias and to the bracatinga are concerned. The problem is that wood, pulp and charcoal are commodity products. To develop new markets requires time, work, and money. I wonder whether the Brazilian business people and knowledge-developers would be interested in doing this. In the case of *Acacia mangium* in Indonesia, there is a strong determination in this respect. A relative success was even achieved in a short period of time. A curious thing is that the papermakers are always interested in some new fiber with a differentiation potential. Therefore, why not beginning to think more deeply about this as well? The problem is that in many people's mind the concern turns always towards competition among these materials or these fibers. One ends up disregarding the potential, without contemplating the advantages offered by forest and industrial synergy that might be obtained. Such things are proper to the human beings. I believe that everything is just a question of studying, researching, making operational and establishing a strategy with much determination and competence. We may be constructing important future alternatives.

In the first of these chapters about *Leguminosae*, I will discourse on the *Acacia mearnsii*, an extremely useful species in Brazil, South Africa and Australia. In the second part of this theme, in another chapter of our book, I will speak about the *Acacia mangium* and the *Mimosa scabrella*.

I sincerely hope that my arguments will be strong enough to attract at least the undertakers' and governments' attention to the potential of these *Leguminosae* for the Brazilian silviculture. They may perfectly reach growth rates vastly superior to the present 15 to 25$m^3$/ha.year, and their woods may be improved still more for numerous purposes, among which pulp and paper, fiber or wooden panels, particle boards, furniture, charcoal, firewood, etc.

You may call in question why someone like me who has always shown the greatest affection for *Eucalyptus* is all of a sudden so enthusiastic about the *Leguminosae* as well!!!! First of all because I foresee the chance of more sustainable forest plantations, as we will have the possibility of alternating plantations or doing plantation rotations, improving the use of the forestlands. Any agronomist like myself knows that alternating uses for the same area of soil is the best way of perpetuating its productive capacity. The rural farmers also know it very well. Keeping an area always with the same crop or type of forest, without any rest, in the long run "weakens" it, exhausting some of its chemical, physical and biological components. Replacing these losses is only possible by means of expensive agricultural inputs and causing greater environmental impacts. The agricultural practices, supported by science, recommend us to alternate crops and that from time to time the soil is allowed "to rest", in order to recover its productive potential.

*Eucalyptus* plantations also consist in a form of intensive agriculture in the areas where these forests are homogeneously planted. In spite of the knowledge already developed to guarantee the sustainability of the forest site productive capacity, to maintain the same area with the same species or genus for long period of years may mean a risk to productivity and to the soil itself. Examples related to coffee and pastures have been already seen in the past, and now we are following attentively the large areas planted with soybean and sugarcane cultures. The *Eucalyptus* trees, the cane and the soybean are absolutely necessary for the human society; we need them for our life and happiness. There are no doubts in this respect. However, science has always recommended to alternate crops, to do their rotation in belts of cultivation or other forms of alternation for better soil utilization. It is something to be included in our researches and knowledge development. If wood is needed for industrial purposes and for use by the citizens, why not produce it from several genera of trees, instead of just a few and always planted in the same forest lands?

There are many things to be learned in agro-ecology. The precision high-tech silviculture has taught us much, but the forest sciences can incorporate new agro-ecological concepts into their fundamentals. Among these new concepts for the forest plantation silviculture, I recommend to focus on the following three:

- <u>Crop rotation</u>: it means to alternate the use of the soil with "forest crops" of distinct characteristics (example: *Eucalyptus* and *Leguminosae*), capable of even supplementing the soil quality. This can be done with alternate planting lands of these genera, or with forest plantations in belts of cultivation. In the operations for plantation reestablishment, a certain forest genus used for a given period of time may be alternated with the use of another genus and so on.
- <u>Soil "rest" in a programmed way</u>: this means not to practice the forest cultivation on the soil any longer than a certain period of time, letting it rest for a while as Nature would wisely teach, as a function of its seed bank and of the micro-life it presents.
- <u>Mixed species forestry</u>: this practice is something like using agroforestry, but only with trees. It consists for instance in planting *Eucalyptus* lines and lines with another forest genus (acacia or bracatinga corresponding to our considerations in this work). Then there will be two mixed species in the same forest area. At forest harvesting the trees may be extracted separately or in a mixed way. When planting *Leguminosae* with *Eucalyptus*, in mixed plantations, we favor the *Eucalyptus*, since the *Leguminosae* offer nitrogen to the soil (nutrient cycling). As to the *Eucalyptus*, as they grow faster, they stimulate the growth of the *Leguminosae,* which enhance their growth rates in order not to be dominated. There are many studies carried out with mixed *Eucalyptus* and *Acacia* plantations that show advantages of this practice. As far as wood quality is concerned, we will have a more heterogeneous wood; there is no doubt about it. However, depending on the use, it would behave well: pulp and paper, firewood, coal, fiber panels. The production of many industrial goods is based on wood blends. In the Northern Hemisphere, kraft

pulp production from natural forests presents always this situation. Even at many kraft pulp companies in Brazil the mill wood supply is based on a pre-established mix of *Eucalyptus* woods of different ages and densities. Almost all companies practice wood mixtures of *Eucalyptus urograndis, E.saligna*, *E.grandis*, *E.globulus*, *E.dunnii*, *E.urophylla*, etc.

I have worked during 19 years for Riocell S/A, a *Eucalyptus* kraft pulp mill in the State of Rio Grande do Sul, Brazil. At present the mill belongs to Aracruz Celulose S/A. There, for approximately 20 years, the company has produced bleached market kraft pulp containing about 25% of black wattle (*Acacia mearnsii*) wood based on volume (or about 30% in weight, due to the higher basic density of black wattle wood). The black wattle wood is abundant on the wood market of the State of Rio Grande do Sul, all this wood and trees being produced by local tannin companies and acacia planters. Riocell did not plant black wattle; they purchased the wood on the local market. After all, this wood was and is still available in relative quantity in that Brazilian State.

I would like to make two interesting records about this period I worked for Riocell, reporting two singular situations to the black wattle advantage, whether of forest or industrial type:

1. All the company foresters knew very well that when they had to plant *Eucalyptus* stands in soils that had been previously cultivated with black wattle; the *Eucalyptus* forest yields were exceptionally higher. The forest grew faster, was more vigorous, healthy and productive. Then there was always an interest in looking for this type of land in the process of rural estate acquisitions. The richness of the soil microbiology, the higher nitrogen content, the better structuration and porosity, the higher organic carbon content: all theses features were very much appreciated by the new *Eucalyptus* forests planted in those areas.
2. Some market pulp customers who imported the bleached pulp for tissue paper manufacturing demanded a certificate issued by the quality area, guaranteeing that the acacia fiber content was within a minimum value. The preference for this mixed pulp was due to the drainage and dewatering facility that the black wattle fibers aggregated to the paper web. At tissue paper manufacturing, performed with very fast-speed machines, the paper web drainage and consistency at the wet-end outlet are important manufacturing aspects. In both cases, the acacia fibers helped improve these industrial performance characteristics.

Riocell stopped consuming black wattle wood purchased on the local markets due to an unbalancing in their *Eucalyptus* wood production. Cherishing a strong expansion in pulp production in the early nineties, the company had a large *Eucalyptus* own plantation plan and had also promoted the plantations of *Eucalyptus* in that region. Nevertheless, the delay in mill expansion ended up demanding the consumption of these additional sources of *Eucalyptus* woods when they reached maturity.

The black wattle wood that was purchased by Riocell soon found new customers: the pulp and paper mills in Japan. At present, the noblest black wattle wood is practically exported abroad in the form of chips or logs. About 50% of the wood production of the *Acacia mearnsii* forest plantations of the State of Rio Grande do Sul follows international routes. A significant part of the tannin manufactured from the extraction of its barks also travels abroad. Brazil is an important natural tannin manufacturer for the world markets.

Conclusively, the industrial and forest aspects of the *Acacia* culture and the *Eucalyptus* plantation forestry complement each other very well. There are significant advantages showing that the ways leading to the future are promising. What has been already a success in the past (f.e.: use of wood blends for kraft pulp production) may occur again under new technological and market-related points of view.

I will wait for these new times, but will try to exert an influence for them to come as soon as possible.

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## THE ACACIAS

***Acacia*** is a botanical genus comprising many dozens of species, most of them originating in Australia, in the same way as the *Eucalyptus*.

Since the acacias have a high potential for dissemination by the germination of their seeds, in Australia it is common to find these two genera coexisting in natural forests. Both acacias and *Eucalyptus* encompass hundreds of species, varying from the shrubby to the tree species. For this reason, the coexistence between *Eucalyptus* and *Acacia* in their region of origin may mean both competition and cooperation, since both genera can compete with and complement each other as well.

Among the many species of *Acacia*, there are some having intense commercial utilization, or else in agroforestry or soil protecting systems: *Acacia mangium*, *Acacia mearnsii*, *Acacia melanoxylon*, *Acacia crassicarpa, Acacia auriculiformis* and *Acacia saligna*. For Brazil and Latin America in general, the forest species of acacia of greatest interest are as follows: *Acacia mearnsii* and *Acacia mangium*. Both of them show good adaptation in some Latin American regions and may give rise to forest stands and products of reasonable to good qualities. As their woods are rather indicated for firewood, coal, pulp, paper, wooden panels, etc., they may constitute promising alternatives for agriculture and silviculture, allowing the farmers to obtain other revenues, as it is the case of selling the *Acacia mearnsii* bark for tannin and tanning compound extraction.

The acacias are very much used in agroforestry systems by small and medium size landowners. These farmers find in the acacias forms of providing a "rest" to the soil after an intense use by the conventional agriculture. For a not very long period of time the farmers let the soil resting with acacia and improving as to its biology, nitrogen richness and structuration are concerned. At the same time they are adding income to the rural estate by selling the wood and the bark (in the case of black wattle). The black wattle, for these recently mentioned reasons, is also used to recover degraded areas, especially those due to mining, as well as other ones where there occurs removal or degradation of the fertile superficial soil.

There are also large companies in the world, planting acacia forests for industrial use of the wood and the tannin rich bark. Although the forest technology levels are still inferior to those practiced with *Eucalyptus*, there is much room for significant product and forest productivity and quality gains. Thus, expectations regarding more intense popularization of commercial acacia plantings exist. In case a greater support is provided on the part of the governmental research organizations and the forest companies themselves, the way to this more promising future might be shortened.

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# THE *Acacia mearnsii* IN BRAZIL

In Australia, where it is natural, the *Acacia mearnsii* is known as "black wattle", which means "black stick or black rod". In Brazil it is known as *"acacia negra"* due to the fact that its logs, after debarking, darken right away due to oxidation of the tannins and extractives present in it.

Its taxonomic identification and its botanical description in Brazil were a little conflicting and arduous, because many acacias species are very similar in their morphology. *Acacia mearnsii* has been already called previously *Acacia decurrens* or *Acacia mollissima* in Brazil, at the beginning of its plantations. Its correct identification resulted after some polemic conflicts and debates among the botanists.

The *Acacia mearnsii* has been successfully planted in several countries, in addition to its country of origin. Its forestry and economic value are recognized in South Africa, Madagascar, USA (California), Chile, Argentina, etc.

The first attempts to introduce it in Brazil go back to the mid-1910's, when some plants have been introduced into the region of Sao Leopoldo, state of RS. However, it is accepted that only from 1928 onwards it began to be cultivated in forest plantations for wood production. The seed availability was low and the seeds had to be obtained from the few trees existing in the country at that time. It is reported that in 1928 Mr. Julio

Carlos Lohmann has planted 9,000 plants in the form of a small forest stand in the town of Estrela, RS, and for this reason he is considered to be the pioneer in this type of silviculture in Brazil.

The main purpose of introducing the species into Rio Grande do Sul was to obtain tannin from its bark, since the leather and footwear industry has been always prominent in that Brazilian state. As the region of Vale do Rio dos Sinos is an important leather and footwear manufacturing region in Brazil, the black wattle was brought as an alternative to tannin production. The amount of tannin and soluble tanning substances in the black wattle bark may range from 20 to 30% of its dry weight, something absolutely fantastic. The black wattle tannin is considered to be an ecologically correct product due to the fact that it is little aggressive and little toxic and is obtained from a renewable source. At present, it is mainly used for shoe sole leather tanning, since it adds flexibility to this leather. Its main competitors are the chromium compounds, more difficult to be assimilated by Nature because they are heavy metal salts. Brazil – in fact the State of Rio Grande do Sul – rivals at present the great tannin world producers, which are South Africa and China. Approximately 40% of the Brazilian black wattle tannin are exported to a good number of countries.

After tannin extraction, the residual bark may still have several purposes and uses, as composting for organic fertilizer production, or the use as biomass fuel.

The tannin manufacturers prefer to purchase the black wattle bark still in fresh ("green") state, 7 to 15 days after its removal from the tree (harvesting), at the most. Thus, the bark is healthy and free from decaying fungi and the tannin is extracted therefrom in larger quantity and better quality.

- Taxonomy of *Acacia mearnsii*:

Kingdom: Plantae
Family: *Fabaceae* or *Leguminosae*
Genus: *Acacia*
Species: *Acacia mearnsii*

- Botanical description:

Tree or shrub that can range from 5 to 25 meters in height, with 4 to 40 cm in diameter at breast height.
Smooth bark, dark green at still young trees and gray/brownish at grown-up and mature trees.

Thin branches.

Twice pinnate compound leaves, with small leaflets. The compound leaf is about 8 to 12 cm long, while each small leaflet is approximately 3 mm long. There are 15 to 70 pairs of leaflets per leaf. The inflorescence is globular, bright yellow colored, having about 20 to 30 flowers per little bunch.

Fruit: dry legume fruit, containing 6 to 12 seeds per legume fruit.

Small seeds, measuring 2 to 3 mm, almost square. There are about 40 to 90 thousand seeds per kilo of seeds.

25,000 seedlings are produced from one-kilogram seeds, as in general 3 to 5 seeds are used per seedling container when seeding. The seeds have a hard seed coat, requiring a hot water pretreatment to break it and thus to interrupt this type of dormancy. For this reason, acacia seeds tend to germinate in the field after some fire incidence in the area. It is common to inoculate bacteria of *Rhizobium* genus into the seeds when planting them. This can be done by using acacia plantation soil in the seedling substrate or by the very inoculation of strains of those nitrifying bacteria.

Flowering begins early; flowers can be already noted at 18 months of age. The floral developments are intense and occur between August and November, at the beginning of spring. The seeds ripen in a few months, so that they are ready for being collected as early as between November and January. The major pollination is due to wasps and bees and therefore the acacia honey is also very much appreciated and common. There are male and female flowers in the same inflorescence.

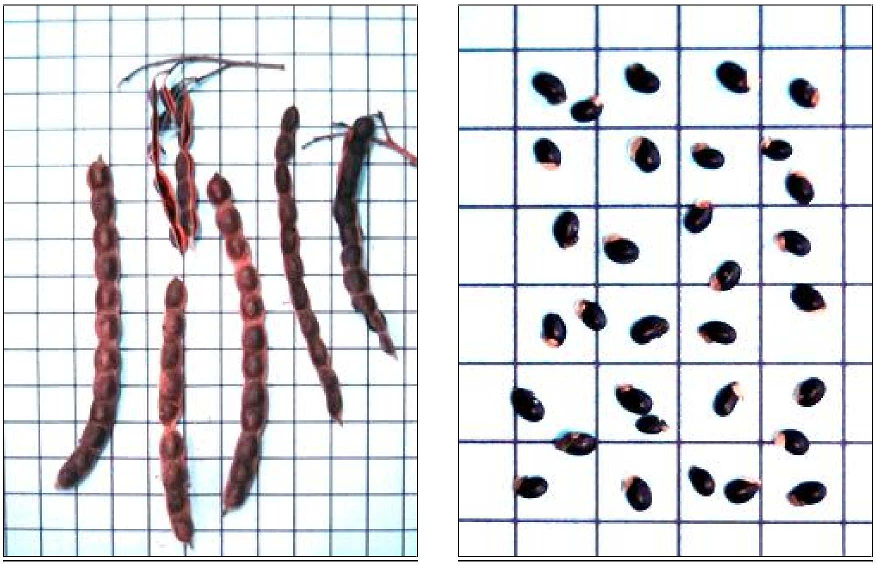

Barks and trunks of young and mature *Acacia mearnsii* trees

Compound leaves and leaflets of *Acacia mearnsii*

Inflorescences, flowers and floral buds of *Acacia mearnsii*

Young *Acacia mearnsii* tree (18 months of age) in full flowering period



*Acacia mearnsii* fruits and seeds
Source: Forest Science Department Herbarium
UFSM – Federal University of Santa Maria
http://coralx.ufsm.br/herbarioflorestal
http://coralx.ufsm.br/herbarioflorestal/img/especies

The black wattle is a temperate climate species enduring well somewhat warm and cold extremes. Its region of natural occurrence is that of 30ºS parallel, which crosses the Australian State of New South Wales and the region of Natal, in South Africa. In Brazil this corresponds to the State of Rio Grande do Sul, where is its largest plantation area in Brazil. In South Africa there are statistics indicating that about 130,000 hectares are planted with *Acacia mearnsii*, which is about a 10-year-long from planting to harvesting cycle.

The species likes well-drained, not flooded soils. Due to its superficial root system, it manages to grow well in shallow soils in depth, although in these situations there is the risk of falling trees due to the strong winds of the region. *Acacia mearnsii* manages to endure well low temperatures even slightly below 0° Celsius. It resists frosts well and tolerates temperatures of approximately 40ºC or slightly over. However, it is only occasionally that it accepts such extreme temperature situations, like 40ºC or frosts. In case they occur often, the plants begin to suffer from stress. It grows well at altitudes ranging from 100 to 1,000 meters and needs well-distributed rains of 800 to 1,500 mm per year. In short, it is a species that seems to have been made to grow well in the State of Rio Grande do Sul, in Uruguay, and in some regions of Chile and Argentina.

As the trees are *Leguminosae* with high nitrogen fixation capacity, they are less demanding in terms of soil fertility, but they need phosphorus, since this nutrient is scarce in Brazilian soils. Although they do not require nitrogen fertilization, they should not be considered to be species for weak and bad soils, requiring no fertilization. In case of richer soils or when adopting a supplementary soil analysis based fertilization, the plants grow faster, becoming more vigorous and healthy and the productivity is rewarded.

The black wattle planting to harvesting cycle in the State of Rio Grande do Sul extends for 6 to 8 years. Nevertheless, there are many rural farmers interested in anticipating the bark sale income, so that they harvest the forest between 3 and 5 years of age, which is an economic and environmental loss. They even are used to plant many more trees per hectare, as they are already planning forest harvesting at too early an age. By doing this anticipated forest harvesting they end up putting into practice a bad quality silviculture, produce thin trees small in diameter, obtain little wood and do not allow a good cycling of nutrients to occur, which might return to the soil by the deposition of more leaves, branches, flowers and fruits, in order to form a thicker organic litter on the soil.

The black wattle forests in the State of Rio Grande do Sul still deserve much more forest research in order to develop better and more healthily. The tree mortality is still high, reaching about 30 to 40% under the most common conditions. In high stress and competition situations, the acacia suffers a heavy attack by fungi of the *Phytophthora* genus, which cause a disease well known as gummosis. Even healthy trees are attacked. The black wattle is very sensitive to these fungi and up to this date the Brazilian forest science did not develop a solution for this disease, not even more resistant or tolerant trees. The solution would be to find gummosis-resistant trees and to develop a process of cloning in order to multiply the resistant individuals. Something similar to that done with regard to the hybrid *Eucalyptus urograndis*, in order to solve the *Eucalyptus* canker problem, a fungal disease that put at risk the *Eucalyptus* plantation forestry in Brazilian tropical regions around the seventies and eighties. If the gummosis problem is solved, the acacia culture will gain new forces and will grow much more; we have no doubts about this.

Young and grown-up *Acacia mearnsii* trees attacked by *Phytophthora* gummosis

The black wattle trees show a very good initial growth, they occupy well the space offered to them and compete well with the underbrush. Obviously, the forest technology requires weed combat and the monitoring of the understorey competition. It is evident to the acacia forester that the operational practices developed for the *Eucalyptus* may be useful to him. We may cite: combat against the cutting ants and the understorey competition, the soil preparation to avoid radicular growth hindering layers, the mineral fertilization through soil analysis, etc. It is not because the black wattle is a sort of nitrogen fixing leguminous plant that it should be considered to be magnificent and omnipotent.

In part, the black wattle silviculture and genetic improvement did not develop so intensely as for the *Eucalyptus* due to the fact that the species is planted in small or medium sized rural farms as a supplement to the farm income. Furthermore, there are only two large companies involved in black wattle product commercialization in Brazil: Seta S/A and Tanac S/A. Had the acacia business further important players in the country, the corresponding research would be certainly much more advanced. Except for these two large companies, that have larger planted areas, the rural farm landowners planting black wattle in the State of Rio Grande do Sul have 20 to 200 hectare plantations in each of their farms. They plan their plantings so as to have forests of different ages, in order to guarantee every year a sustained income to their business. As the acacia has a 6 to 8-year cycle, it is perfectly possible to note that each rural farmer plants about 2 to 30 hectares per year.

As the farmers know the acacia advantages enriching the agricultural soil by nutrient cycling, when harvesting an acacia forest they are in the habit of using the land for some type of agriculture separately or associated with a new acacia planting. They know very well that they can have high agricultural productivity rates by using this nitrogen enriched soil for planting annual cultures such as: bean, peanut, watermelon, manioc, corn, potato, tobacco, etc. The practice of agroforestry involving intercalation of a crop planted between the black wattle forest lines in the first year of its life is very common. From the second year onwards, as the canopies close up, the farmer releases the cattle or the ewes to let them feed on the forest understorey, as the latter begins to develop vigorously.

The black wattle is planted in tight spacings (4 to 5 square meters per plant i.e. 3.0 x 1.33 m; or 3.0 x 1.5 m; or 3.0 x 1.66m). The reason for it is the high mortality expected. 2,000 to 2,500 trees are planted per hectare, expecting to harvest about 1,200 to 1,700 at the most.

As a function of the very positive characteristics for agriculture (for the small and medium rural owners), as mentioned, the companies using acacia bark and its wood stimulate and promote the black wattle plantation in the State of Rio Grande do Sul. It is estimated that approximately 45,000 families are involved in the black wattle production chain in the State of Rio Grande do Sul, from its planting to the commercialization of its products.

Young black wattle forest plantation at 2.5 years of age

The available statistics report that there are 120,000 to 160,000 hectares of black wattle forests in the State of Rio Grande do Sul. These figures are very inconsistent, precisely due to planting dispersion in small and multiple areas in the state. There is a concentration in three regions of the state: Montenegro/Triunfo; Arroio dos Ratos/Butia and Piratini/Pelotas. The fact calling most attention in these statistics is that everybody knows that many new plantations have appeared in the past 5 years. The reason for it has been the growth of tannin production for other purposes, besides leather tanning, as well as black wattle wood chip export to Japan. The tannin product export has also maintained a considerable growth. Thus, the foresters who are active in the area dare to estimate that the black wattle plantations in the State of Rio Grande do Sul should be already reaching 220 to 250 thousand hectares in 2008, a figure requiring confirmation. It is well-known that there are many small plantations that certain ill-informed farmers, or having little forestry knowledge, cultivate to harvest the bark of the trees at 3 or 4 years of age: it is an environmental and forest-related nonsense, showing how far we still are from a high-tech silviculture, as far as this forest business in full growth is concerned.

Considering these so distinct data and with equally very different forest productivity rates, due to a non-standard silviculture, it becomes difficult to guarantee which is the planted area and which is the yearly harvested area in the State of Rio Grande do Sul. It is estimated that about 20 to 25 thousand hectares of acacia plantations are yearly harvested in the state. Likewise, it is very difficult to obtain an average wood production value per hectare, since there are different forest technology levels, different sources of genetic material and different harvesting ages (between 3 and 9 years). This means that statistics are really little conclusive. The only really correct thing is the amount of bark purchased by both tannin companies. As the bark of every acacia plantation is removed and sold – as otherwise its existence would not make any sense –, it is possible to do a reverse engineering and determine the amount of offered wood from the amount of bark produced.

A further *Acacia mearnsii* product: honey

In addition to its advantages as raw material (bark and wood) and for soil conservation purposes (protection against erosion, nitrogen supply, structuration and moisture), the black wattle brings beauty in the rural environment landscaping. Black wattle trees blossom intensely, become yellow colored in spring, and this gives birth to a landscape which is very much appreciated by the travelers observing them. Furthermore, as the plantations occupy small areas, they are seen as small "forest islands" rather than as forests planted as a monoculture. The foliage of the trees is dark green, a color matching very well the light green of the rice plantations covering these same regions where the black wattle is planted in South Brazil.

When reaching maturity at 6 to 8 years of age, the trees are 12 to 20 meters high, 10 to 15 cm in diameter at breast height and have average volumes of 0.08 to 0.15 $m^3$ with bark per tree. Cycles longer than 8 to 9 years are not recommended, because the rate of mortality increases due to both gummosis and the attack by an acacia wood-boring beetle known as "*cascudo-serrador"* (*Oncideres impluviata*). Bundling up the branches and burning them after the forest harvesting combats this beetle. As a result of this practice, which is even recommended by legislation, the acacia wood-boring beetle is at a manageable level in the state. By this method, the emerging larvae and the eggs deposited by the female insect in small incisions in the bark are killed. At more advanced ages the forest stand health is affected and the forest, instead of growing, begins to lose trees and the wood quality worsens.

*Acacia mearnsii* has been also very much used as a species to recover soils degraded by mining and high erosion, as well as for vegetable covering of full landfill areas. In these situations its productivity is not so high, but its mission is to recover the soil quality, which at last it manages to do very well, as shown by several academic researches.

*Acacia mearnsii* may be also used for green fertilization. After forest harvesting, as the branches and treetops are burned to eliminate the pest represented by the acacia boring beetle, the seeds that are in the seed bank of the soil lose their dormancy by the action of fire. Many of them germinate and give birth to little acacia plants scattered on the ground. This number goes as far as to reach an amount between 15 and 20 thousand little plants germinating per hectare. The black wattle plants are let to vegetate for some time and thereafter they are cut and left over the ground. The nitrogen rich organic residues remaining on the surface (aerial part of the plants) and in the soil depth (nodulated roots) are excellent green fertilizer to the soil.

Some farmers try to deal with this spontaneous acacia germination by thinning it with a sickle or a hoe, trying to leave 2,000 to 2,500 plants per hectare. By doing this, they populate the area with a new forest without the need of using seedlings. This situation does not differ much from another type of silviculture practiced by some rural farmers. They do not plant their black wattle forests from previously prepared seedlings, but from seeds that had the dormancy previously removed with hot water. In both above described situations, silviculture is of course precarious and the expected productions are lower, but even so these situations are considered to be advantageous for someone having little capital to invest in forestry with more advanced technology.

It is curious that the forest scientists in the State of Rio Grande do Sul have tried to research much more the environmental gains offered by the black wattle than its forest productivity in terms of bark and wood. When both things will be achieved, with higher growth rates, as far as volumes and weights of forest products on the acacia planted, and with the environmental gains provided by the plantation, the black wattle may become one of the most fantastic forest opportunities offered to Brazil and to countries with similar climate and latitudes.

At present, with the present forest technologies adopted, the black wattle forest productivity is very variable, ranging from 100 to 200 solid cubic meters of commercial volume of trees with bark per hectare, at 7 years of age. Considering that already exposed above, these so big differences are easy to understand. This is equivalent to 170 to 320 steres per hectare of logs with bark. Stere is a cubic meter of stacked wood logs. It is curious to note that at the black wattle forest production both bark volumes and weights and wood volumes are of interest. Differently from other species, the acacia bark is extremely valuable; it is its main product. Wood and bark combined correspond to the success of black wattle business. But as a matter of fact success only occurs as a function of the need for raw material for the tannin industry. If it grows, the acacia culture will grow as well. If it stagnates, no new acacia forests should appear, as only wood does not stimulate the forest plantation: in such cases it would be better for the farmers to plant either the *Eucalyptus* or the *Pinus*.

Bark represents about 12 to 18% of the commercial volume of the aerial part of the tree. Therefore, the amount of bark ranges from 15 to 30 cubic meters per hectare at the forest harvested at 7 years of age. The bark thickness is low, ranging from 3 to 6 mm. The basic density of the wood is high, ranging from 0.55 to 0.63 g/cm³. The basic density of the bark is lower, ranging from 0.4 to 0.45 g/cm³. Thus, the proportion of bark in the dry weight of the aerial part of the tree ranges from 8 to 11%. In terms of bark dry weight production at forest harvesting, this may range from 6 to 12 bone dry tons (bdt) per hectare at 7 years of age. As bark is sold in green state 7 to 15 days after forest harvesting, the green weight of bark corresponds to approximately twice its bone dry weight (oven dried at 105ºC), as a function of bark moisture.

After bark removal, the wood production of each hectare at 7 years of age ranges from 90 to 180 cubic meters of wood, or 150 to 300 steres (st). Consequently, the average annual growth rate in terms of black wattle wood ranges from 15 to 26 $m^3$/ha.year or from 22 to 40 st/ha.year. It was already seen that at harvesting each tree has a volume with bark ranging from 0.08 to 0.15 $m^3$. A great advantage presented by the acacias is their "shape factor" (commercial volume to cylindrical volume ratio). Ranging from 0.55 to 0.6, the shape factor values are considered to be excellent, while the "stacking factor" (solid volume to stere volume ratio) is poor as a function of the small log diameters. A much larger amount of acacia than *Eucalyptus* logs is required to compose one stere of stacked wood. As a result of it, caging increases and the stacking factor ranges from 0.58 to 0.62 (average accepted in the general calculations = 0.6).

In terms of total wood productivity of the plantation, there are 3 types of situations for the *Acacia mearnsii* forests in the State of Rio Grande do Sul:

- Bad forest stands with inferior silviculture: 20 to 30 st/ha.year
- Medium forest stands with reasonable silviculture: 30 to 35 st/ha.year;
- Superior forest stands with better genetic material and suitable silviculture (for the today's most advanced standards): 35 to 40 st/ha.year.

Nowadays, productivity values higher than 40 st of wood/ha.year are exceptionalities. However, they may become a common situation if genetic and silvicultural improvements are performed in addition to the supply of technical services and financing procedures for forest input acquisition (fertilizers, herbicides, insecticides, etc.).

Survival is still the great problem for acacia forestry. For dense plantations, with about 2,500 trees per hectare, survival is low (from 55 to 65%). For opener spacings (5 to 6 $m^2$/plant) and for improved seed forests and proper silviculture, survival may reach 75 to 85%. The number of trees getting lost along the forest rotation is still large. Mortality is a function of spacing, of the forest site quality, of the silvicultural practices adopted, of age, of the attack by gummosis and by the wood-boring beetle, and of the genetic quality of the seeds used. The tighter the spacing, the worse the growth rate, the lower the average forest BHD (breast height diameter), the lower the average height, the worse the general forest conditions, the easier the obvious phenomenon occurs: survival decreases and mortality increases. Worse the forests, worse the seedlings, the worse the genomes, the worse the infestation of pests and diseases, all these factors contribute to lower productivity and profitability rates. In general, as already seen, when planting 2,000 to 2,500 trees per hectare, the forest harvesting expectation corresponds to 1,200 to 1,700 trees.

Being aware of this, it is vital that the forest producer chooses his way to go. When planting many trees per hectare and wanting to spend little with technology, he may be expecting to earn much because the minimum expenditures on silviculture. However, his return on investment rate will be affected and he will earn less. This is the real life: to get good profits, technology and appropriate silviculture are essential.

*Acacia mearnsii* tree bark and wood

For comparison purposes, in case of good acacia plantations with suitable effective technology, the following forest productivity rates may be reached:

- Average annual growth rate: 40 st/ha.year of tree with bark
- Average annual growth rate: 35 st/ha.year of debarked wood
- Shape factor of the trees: 0.58
- Average height: 15 to 20 meters
- Average BHD: 11 to 15 cm
- Average solid volume of each tree with bark: 0.11 – 0.13 $m^3$
- Dry bark production at 7 years of age: 9 to 11 bdt/hectare
- Green bark production at 7 years of age: 18 to 22 t/ha
- Wood production at 7 years of age: 220 to 250 st/ha (140 to 150 $m^3$/ha)

It will be seen later on in this chapter that the wood obtained from the acacia plantations, independently of its forest quality, is classified into three types: pulp quality wood, thin firewood and black firewood (wood attacked by gummosis). The above-indicated productions encompass these three types of wood.

With regard to bark production and acacia plantation harvesting, the farmers prefer to carry out these activities in the months between two agricultural harvesting times (Winter). This causes an undesirable seasoning for the purchasers and users of bark and wood. If the bark accumulates and takes a long time to be consumed, it will easily decay. For this reason, it is common for the bark consuming companies to adopt the purchase of upright forest stands (living forest stands) in certain periods of the year, in order to harvest them by their own, according to their requirements.

At present it is recognized that spacing between trees is fundamental for the quality of the forest stand, as well as of the products that will be harvested therefrom. If the forest producer is eager to harvest much bark and anticipate income generation, planting too many trees for this purpose, in the long run he will lose or fail to earn more. When focussing on bark, rather than on wood production, one is in the habit of using 4 $m^2$/plant. If the producer wants also good quality wood in addition to bark, he may use a little opener spacings, ranging from 5 to 6 $m^2$/plant. At the present technological stage, spacings opener than that are not indicated. This is due to the present stage of silviculture and genomes availability.

The production of logs larger in diameter improves the stacking factor. As a consequence, each wood stere will offer further advantages to the user of the wood, whichever its use.

The black wattle, as a function of its present forest breeding stage, is not yet so specialized for trunk production. It produces much slash and leaves. This is good for nutrient cycling, but is unfavorable for the main forest products. The black wattle LAI (Leaf Area Index) ranges from 3 to 5 square meters of leaves per square meter of soil area. The proportion of leaves in the aerial biomass is high, between 5 and 10%, depending on the forest age and spacing. Therefore, there are many nitrogen rich leaves to be offered to the soil. The wood in general corresponds to 70 - 80% of the dry weight of the aerial part of the tree, while the bark corresponds to 8 - 11 %. The remainder consists of thin branches, treetops, flowers, seeds and fruits.

Leaves and branches are nitrogen, calcium, phosphorus, potassium and magnesium rich. For this reason, they are important sources of nutrients to the soil, both during forest growth and after forest harvesting. The harvesting organic residues can be spread or bundled up over the soil and the very nitrogen rich leaves fertilize the soil in the form of a green fertilizer.

The bark, which is removed for sale, takes with it many nutrients such as calcium, potassium, phosphorus and magnesium. The wood does likewise. For this reason, the mineral fertilization of the new forest that will be planted in the area is important, as well as for the agricultural cultures. It was already seen that the black wattle is not miraculous, it also consumes mineral constituents of the soil. An interesting alternative is to return industrialized bark residues to the soil, in case they are not consumed as biomass fuel or are not composted for organic fertilizer production.

As the branches are used to be burnt for acacia wood boring beetle egg and larva eradication, the ashes generated in the burning process may be spread over the soil. This is to prevent a heavy rain from removing them from the ground. Ashes from biomass boilers burning the acacia bark or firewood are also welcome to return to the soil for back nutrient incorporation.

As to the stubs or stumps left in the soil after forest harvesting, they undergo a quick decomposition due to their mineral richness. These stubs do not sprout again, like those of *Eucalyptus* trees. Within 4 years at the most they will be decomposed and incorporated into the mineral and the organic carbon composition of the soil. It should be also remembered that the biological activity in acacia plantation soils is very important.

The black wattle stumps sprout very badly. Special conditions are required for the tree to sprout. Unfortunately, this part of the tree (transition region between tree stem and roots up to the BHD) is precisely that part of the tree which is mostly attacked by gummosis. It is still a little juvenile part. The acacia uses to sprout anew when it is felled at a higher point with regard to the soil, but it needs some special conditions for such. On the other hand, it is very seldom that a stump sprouts again.

The success of the acacia silviculture in Brazil had as leverage factor the establishment of both Brazilian tannin producing companies along the forties. The companies SETA and TANAC have excellent entrepreneurial health and maintain a rhythm of growth in their business, which has given rise to the growth of this forest activity in the State of Rio Grande do Sul. The development of tannin uses for purposes other than leather tanning, such as water and effluent flocculants, wood board panel glues, etc., has contributed to the success of this business. This has been achieved by aggregating new technologies by means of research and development at these companies.

Another important entrepreneurial and industrial activity carried out with acacia wood is charcoal production. This charcoal has both domestic (barbecues, etc.) and industrial use (steel production). It has been also used to manufacture activated carbon for food and pharmaceutical industries. Black wattle activated carbon is an important input for purification of food, pharmaceuticals, beer, solvents, refreshments, wines, etc.

At the recent millennium turn, the companies SETA and TANAC began to export black wattle wood chips for pulp production. After over two decades that this wood was used in the State of Rio Grande do Sul for manufacturing kraft pulps (Riocell S/A) and NSSC – neutral sulfite (Cia.

Pedras Brancas), it was natural for this wood to be looked at as an alternative for this important business. The purchasers of these chips have been Japanese kraft pulp and paper manufacturing companies.

Someone who does not know this production chain can be only surprised by its economic, social and environmental diversity and the dynamic driving it offers to the State of Rio Grande do Sul. We have seen the products offered by the forest: wood, bark and nitrogen for the soil. We have also seen the resulting economic outputs: tannins and derivatives, honey, pulp, paper, charcoal, activated carbon, energetic biomass, wood panels and particle boards, organic compost, etc. Definitively, it is an exceptional agribusiness aggregating wealth, value, income, employment and opportunities for economic and life quality improvements in that region.

It would be very easy to integrate this chain into the production chain of *Eucalyptus*. Thus we would be further progressing to the entrepreneurial and biological diversity and aggregating more sustainability to the undertakings that would be involved in this clusterization of agriculture, forest and industry. This is something I have already commented before, but I am reinforcing it now for conceptual consolidation.

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## *Acacia mearnsii* SILVICULTURE IN BRAZIL


It was already commented that the black wattle silviculture still requires technological upgrades, in both genetics and silvicultural practices.

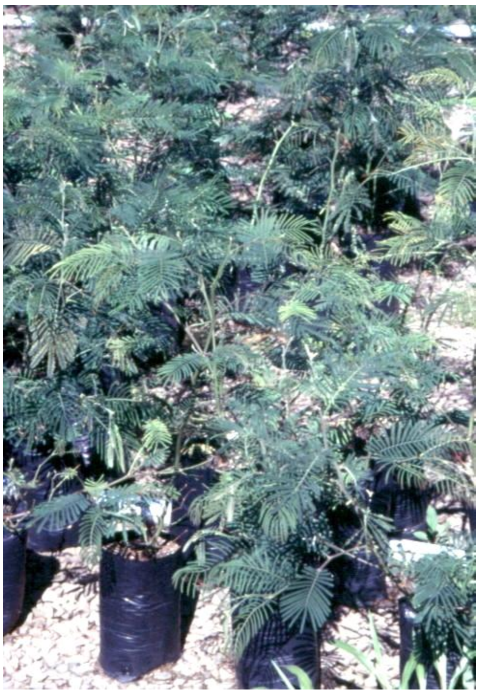
Due to the fact it is a regional culture, involving just a few companies, the research effort is small and has been more strongly directed only by the following research organizations:

Embrapa Florestas – Colombo/Parana
Federal University of Santa Maria – UFSM
Federal University of Parana – UFPR

To have an idea of the level of primitive foundations as regard to the silvicultural aspects of the black wattle, it is enough to mention that most plantations are based on seeds without any genetic improvement and collected at anthills. The cutting ants take these seeds to their homes to remove the part corresponding to the aril, thereafter throwing away the hard seed, without any use for them, in the anthill garbage area. Aril is the coating totally or partially wrapping up the seed, a result of the residue from the upper part of the ovule holder (ovule peduncle). To have an idea of what is the aril, the passion fruit has it pulpous and orange-colored, covering the seeds of that plant.

Thus, easily finding the seeds at the anthill, the acacia seedling producer will collect this material almost without any effort. No comments on the genetic quality of the material.

The fact that many seedlings are still produced in plastic bags, the unjustifiable high mortality along the cycle and the lack of solution for the gummosis problem are clear indications that immediate and incisive action is required with regard to the black wattle silviculture in the South of Brazil.



"Obsolete technology" - black wattle seedlings in large plastic bags

Differently from the *Eucalyptus*, where emphasis on forest research has been very strong due to the great entrepreneurial and economic power involved throughout the country, there is in the acacia silviculture and business a strong competition among the few players. The technological gains have been reduced and the cooperative research almost inexistent. It was only more recently that cloning, vegetative propagation, genetic improvement and production of improved seeds began to be deeply studied. In terms of forest protection, researches are focussed on reporting and quantifying the problems, rather than on effectively solving them.

To know more about *Acacia mearnsii* silviculture in the State of Rio Grande do Sul, I suggest to access the websites listed in the following:

- EMBRAPA FLORESTAS. **Black wattle cultivation** (2002).

Available at:
http://sistemasdeproducao.cnptia.embrapa.br:80/FontesHTML/AcaciaNegra/CultivodaAcaciaNegra/index.htm

- TANAC. **Forest Unit. Acacia culture**. Specialized website.

Available at:
http://www.tanac.com.br/PT/institucional.php?codCategoriaMenu=154&nomArea=Acacicultura&codDado=10&menu=138

- Mochiutti, S. Productivity and sustainability of black wattle (*Acacia mearnsii*) plantations in the State of Rio Grande do Sul. PhD Thesis at the Federal University of Parana (UFPR)]. 286 pp. (2007)

Available at:
http://dspace.c3sl.ufpr.br:80/dspace/bitstream/1884/10306/1/Tese+Silas+Mochiutti[1].pdf

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## DIFFICULTIES AND OPPORTUNITIES IN *Acacia mearnsii* FORESTRY IN BRAZIL

In spite of all acknowledgement of the fact that this is an excellent agribusiness for the small and medium sized rural producer, the black wattle is still facing difficulties in Brazil to start off and to proceed as a country-wise forest species. It has been considered as something regional of the State of Rio Grande do Sul, to supply the tannin industry and thus derive some other parallel business therefrom. The pulp and paper industry, the charcoal-based steel manufacturing industry, and the solid wood product manufacturing industry do not yet consider it as an alternative to what they are already doing at present with other forest species, like *Eucalyptus* and *Pinus*. It is worse than that; they do not even consider it as something complementary to those species. The black wattle agribusiness only sustains itself in the State of Rio Grande do Sul and in Brazil due to the tannin production. Even wood is considered as a byproduct, although it is valuable, as it is used for pulp, paper, charcoal activated carbon and firewood. If the tannin industry will not grow, or if it will come to suffer some kind of crisis, the acacia silviculture will follow this same trend. If the plantations will surpass the tannin production requirements, bark will be in excess and the price will decrease, so that the business will worsen for the forest producers.

In a clear and objective way, the main barriers to the acacia growth as regional cultivation are associated with:

- Dependence on the simultaneous growth of the tannin business, which means that tannin has been and is likely to continue to be the "driver' of this agribusiness;
- Forest productivity lower than the *Eucalyptus* (in the State of Rio Grande do Sul the good quality *Eucalyptus* plantations yield already 40 to 45 m³/ha.year of wood with bark, or 60 to 65 st/ha.year in average);
- Enormous phytosanitary problems in connection with gummosis, acacia wood boring beetle and even other less impacting ones, as rust.
- Single production cycle, as it does not sprout again and cannot be coppiced for new productions involving less capital requirements;
- Planting and harvesting occur following seasoning periods, due to the fact that the rural producer has labor scarcity at the agricultural harvesting time. The acacia silviculture demands much plantation and harvesting labor. The bark removal is highly demanding in terms of handwork.
- More consistent forest improvement and tree breeding programs are lacking. The maximum forest improvement practiced at present is the introduction of improved seeds from South Africa and Australia, for provenance testing purposes. There are also seed production areas established on the basis of mass selection and some seed orchards planted by the use of seedlings.
- The forest technology is still rather primitive as to many basic concepts (seed provision, types of seedling containers, application of fertilizer and fertilization, ant combat, weeds and underbrush competition combat, planting density, etc.).
- Insufficient orientation as to the wood quality to be produced (for pulp production?; for biomass?; for solid products?, for coal?, etc.).

- Acacia culture lack of definition as a business: is it just an agroforest business for bark and wood sale?; or is it an industrial business with high added value in the production chains it will fit into?
- Lack of a more detailed knowledge about the black wattle value network, which makes possible to find the value aggregation and destruction points. This would allow optimizing that network and maximizing the gains for those involved in the process.

For these reasons, there are important opportunities for the acacia silviculture in Brazil, such as:

- Development of new markets for tannin in the chemical area, even promoting the larger export of this organic product of renewable sources and low environmental impact.
- Increase in forest productivity to average values above 40 st/ha.year in wood volume and over 10 - 12 dry tons of bark at forest harvesting. These values are already obtained at better quality forest stands in the State of Rio Grande do Sul, so that it is something perfectly feasible.
- Strong emphasis on the solution of the black wattle phytosanitary problems, both to avoid growth rate losses and to improve the product quality, as well as to increase the rural producers' net incomes. A high proportion of the produced wood corresponds to the so-called "black firewood", which is the defective wood from the base of the tree, with the necroses and wounds of gummosis. This wood, which might be sold for pulp or wood panel manufacturing, ends up being directed to coal production, which yields less to the producer. Gummosis is so serious a disease, that about 30 to 40% of the dead trees along the cycle have died because of it. Therefore, it is the greatest cause of tree mortality, as well as of the low planted tree survival. Furthermore, even the trees that do not die, but present the necroses, lose value and productivity. Therefore, the losses mean additional costs and reduction in the business results. It is already high time to invest heavily in order to solve this problem.
- Wood quality development for other types of products of higher added value (sawmill, furniture, wood panels, etc.).
- Acacia wood product valuation, so as not to direct the wood any longer just to products of lower value aggregation, such as firewood, coal, and pulp.
- Further studies for the establishment of agro-silvi-pastoral consortia, allowing higher environmental and social quality to the agribusiness companies.
- Further studies for the establishment of forest consortia to deal with acacia associated with *Eucalyptus* and *Pinus*.

- Better understanding of the acacia silviculture value network, its key points of competitiveness, the bases and fundamentals of the business involved, the needs of innovation, etc.
- Reduction in waste and rework along the value network.
- Acacia silviculture image valuation as a profitable culture, socially responsible and environmentally correct.

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## *Acacia mearnsii* WOOD LOG AND CHIP COMMERCIALIZATION

The black wattle forests are harvested by clear cutting, in a single forest rotation, between 6 and 8 years of age. At forest harvesting, the bark is removed, as the tree is still upright and transformed into bundles or small green bark bales for sale to the tannin industry.

Thereafter the trees are felled and traced into 1 to 2.5 m long logs. Many black wattle forests are very irregular and the trees are thin in diameter. Other trees present the base considerably damaged by gummosis lesions. For this reason, the wood is separated into three types of products, each of them with its market and its peculiarities.

- <u>Wood for pulp / chips</u>: it is the noblest and cleanest wood, without bark and without any phytosanitary damages. The minimum log diameter at the thinner end is 5 to 7 cm without bark.
- <u>Thin firewood</u>: it is the treetop and thin tree wood logs, with small diameters and containing some bark. It is oriented to firewood, both domestic and for small business (bakeries, potteries, etc.). It can be also sold for biomass boilers, which use it as logs or transform it into chips.
- <u>Black firewood</u>: it is the wood of any diameter, presenting the lesions of gummosis. The lesions impart a blackish characteristic to this wood, due to the oxidation of the exuded gums and extractives. The bark is difficult to remove and many times accompanies the wood. As gummosis preferably attacks the base of the tree, the black firewood logs are thick and irregularly long. They are considerably directed to charcoal production.

At a commercial black wattle forest stand of suitable forest quality, the following quantities of these three types of wood are harvested at 7 years of age:

- Pulp / chip wood: 150 to 220 st/hectare;
- Thin firewood: 15 to 25 st/hectare;
- Black firewood: 20 to 30 st/hectare;
- Total: 200 to 250 st/hectare


Black wattle woods and chips

In order to compare *Eucalyptus* with black wattle productivity rates, the following table presents some data that may serve as a basis for important calculations to be made by the producers. We have tried to present standard and average data for these two types of woody materials, with results for the 7 years of harvesting age.

Table 01**: Standard values for commercial plantings with good technological basis**

| | ***E.saligna*** | ***E.urograndis*** | ***A. mearnsii*** |
|---|---|---|---|
| Plantations obtained through seedlings from seeds Productivity at 7 years, in st/hectare | 340 - 380 | 360 - 400 | 180 - 220 |
| Clonal plantations Productivity at 7 years, in st/hectare | 420 - 450 | 440 - 500 | - |
| Solid m³/stere ratio | 0.66 to 0.71 | 0.66 – 0.71 | 0.59 – 0.62 |
| Number of logs per square meter, observed in side pattern in the log stack | 40 - 55 | 30 - 50 | 65 – 90 |

| | ***E.saligna*** | ***E.urograndis*** | ***A. mearnsii*** |
|---|---|---|---|
| Shape factor of the trees | 0.48 – 0.53 | 0.48 – 0.53 | 0.55 – 0.60 |
| Average basic density of the wood (g/cm³) | 0.45 – 0.50 | 0.48 – 0.55 | 0.55 – 0.63 |
| Dry weight of 1 solid m³ of wood (bdt/m³) | 0.45 – 0.50 | 0.48 – 0.55 | 0.55 – 0.63 |
| Dry weight of 1 st of wood (bdt/st) | 0.32 – 0.35 | 0.33 – 0.38 | 0.33 – 0.38 |
| Bulk density of recently produced chips (bd kg/m³ chips without compaction) | 155 - 165 | 165 - 175 | 185 - 210 |
| Bulk density of compacted chips in the wood chip pile or in the ship hold during transportation. (bd kg/m³ chips) | 175 - 185 | 185 - 200 | 205 - 230 |
| Conversion factor of wood into chips (m³ chips without compaction per stere of wood logs) | 2.0 – 2.1 | 1.9 – 2.1 | 1.8 – 1.9 |
| Conversion factor of wood into chips (m³ of chips without compaction per solid cubic meter of wood logs) | 2.9 – 3.1 | 2.8 – 3.1 | 3.0 – 3.2 |
| Chip volume per bone dry ton of wood (m³/bdt) ratio | 6.1 – 6.7 | 5.7 – 6.1 | 4.8 – 5.5 |
| Wood moisture when just felled tree (%) | 55 - 60 | 52 - 57 | 47 – 52 |
| Weight of 1 solid m³ of just felled green wood (t/m³) | 1.10 – 1.12 | 1.11 – 1.14 | 1.14 – 1.17 |
| Weight of 1 stere of just felled green wood (t/st) | 0.74 – 0.79 | 0.75 – 0.80 | 0.67 – 0.72 |
| Weight of 1 solid m³ of wood at 25% moisture (t/m³) | 0.65 – 0.68 | 0.68 – 0.72 | 0.73 – 0.84 |
| Weight of 1 st of wood at 25% moisture (t/st) | 0.43 – 0.46 | 0.45 – 0.50 | 0.45 – 0.50 |
| | ***E.saligna*** | ***E.urograndis*** | ***A. mearnsii*** |

**<u>Advantages of commercial *Eucalyptus* planted in Brazil in a comparison to the black wattle</u>**

- Higher forest productivity and greater wood supply per hectare at forest harvesting, at the same cutting age;
- Higher solid $m^3$/stere of wood ratio;
- Fewer logs to compose 1 solid cubic meter or 1 stere of wood;
- Fewer proportion of thin logs;
- Better log conversion to wood chips, with lower sliver and overthick chip generation;
- Less re-chipping required.

**<u>Black wattle advantages in comparison to the commercial *Eucalyptus* planted in Brazil</u>**

- Concomitant wood and bark production for the chemical industry, two products of good market value;
- Higher basic density of the wood;
- Higher dry weight per solid cubic meter of wood in logs;
- Higher dry weight per cubic meter of chips;
- Dry weight of one stere of wood equivalent to that of *Eucalyptus*, in spite of the lower stacking factor;
- Lower chip volume per dry ton of wood (better space occupation at chip transportation);
- Lower wood moisture when felling the trees as a function of the higher basic density of the wood;
- Higher shape factor of the trees.

The exports of *Acacia mearnsii* wood in the form of chips is a forest agribusiness activity that has considerably developed in the State of Rio Grande do Sul in the last decade. As it will be seen later on, the black wattle wood is rather interesting for pulp and paper production. For this purpose, rather than for biomass fuel use, the black wattle wood has been exported in the form of logs and chips. In spite of that, the use of wood as biomass or firewood in Brazil is still considerably expressive.

It is estimated that the yearly acacia wood production, considering its different types, ranges from 3.9 to 4.5 million steres, estimates that have not been obtained from average annual growth rates of wood per hectare or from wood measurements at forest harvesting. It is impossible to make this measurement so as to cover the whole wood produced, since much of this firewood is consumed at the rural estate itself. The best way of quantifying the wood production is by having recourse to the relationship with the sold bark production, since nobody produces acacia bark in order to stock it or to throw it away.

The most recent statistics published point to an export of chips corresponding to about 1 million tons, but there are indications that in 2007 it has reached 1.2 millions. Let's consider this range from 1 to 1.2 million tons of exported chips containing moisture as such i.e. approximately 30%. Then, we will have a bone dry weight based export of 700 to 840 thousand tons. It was recently seen in Table 01 that the dry weight of one stere of black wattle wood ranges from 330 to 380 kg. Admitting an average value of 360 bone dry kg per stere, the export of approximately 2 to 2.35 million steres of black wattle wood per year by the State of Rio Grande do Sul will be obtained i.e. something around 50% of the acacia wood production per year. In the same Table 01 it can be seen that each stere of wood, when converted into chips, yields on average about 1.85 cubic meters of chips. Therefore, the export of chips in volume has corresponded to 3.7 to 4.3 million cubic meters of chips. As in the ocean transportation the chips tend to be arranged and to be compacted in the ship holds, the volume received by the purchaser is about 10 to 15% lower. However, the dry weight, which is what really interests, will be the same. Furthermore, when removed from the ships, the chips lose the compaction caused by the travel and return to the original volume. Very curious all that. But it may cause some confusion for those managing the situation from a distance or not knowing well this logical process involved.

Then, the black wattle chip export has corresponded to 50% of the total wood made available by the acacia forestry in the State of Rio Grande do Sul. This is an achievement for so recent an undertaking. The remaining steres of wood generated by the acacia silviculture during the year, corresponding to a little more than 2 million steres, are directed to local purposes, especially energetic biomass or charcoal production. The proportion of black wattle wood directed to other nobler uses, such as furniture, wooden panels, houses construction material and sawmills, is small or even negligible. But this time will arrive for it; we have no doubts about it. It is already time for the Brazilian science, as well as that of the State of Rio Grande do Sul, to do this for *Acacia mearnsii*, since it has done so much for the State of Rio Grande do Sul.

<u>Sites to be visited in order to get acquainted with the black wattle chip export by the State of Rio Grande do Sul/Brazil</u>:

- SETA Forest Division. **Woodchips**. Specialized website.

Available at:
http://www.seta-sa.com.br/site/mita/woodchips.php

- TANAC. **Chip unit. Wood chip export**. Specialized website.

Available at:
http://www.tanac.com.br/PT/institucional.php?codCategoriaMenu=150&nomArea=Unidade%20Cavacos&codDado=6&menu=138

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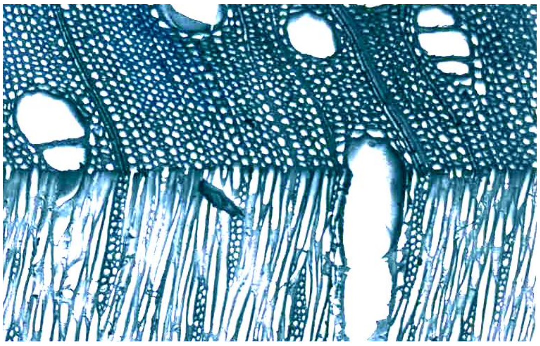
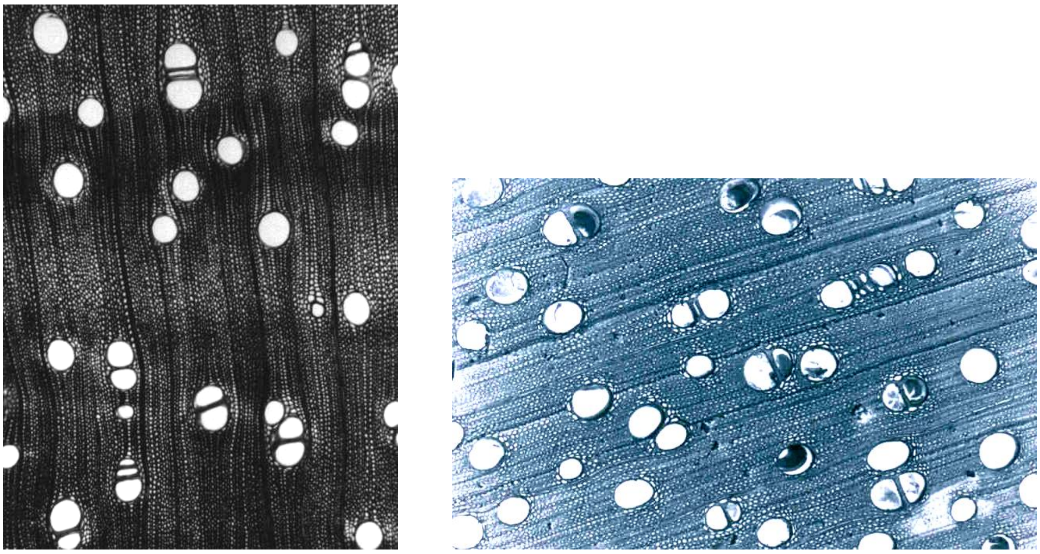
## MAIN CHARACTERISTICS OF THE *Acacia mearnsii* WOOD

- ***Acacia mearnsii*** **wood anatomy**

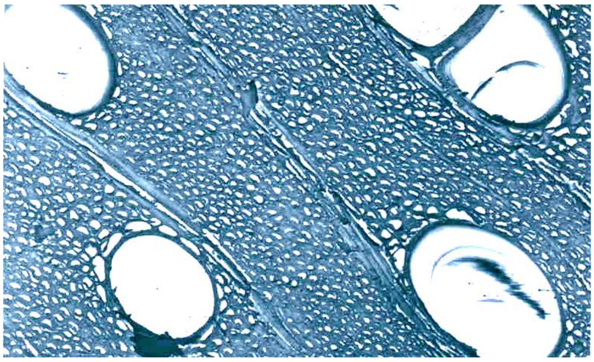
The black wattle wood presents quite distinct heartwood and sapwood, the sapwood having a light chestnut coloring, while the heartwood color is grayish brown. The pores (vessels) are numerous and easily visible with a 10-time magnifying glass. The vessels are diffusely distributed over the cross section of the wood and can be solitary/isolated, geminate or multiple. The vessels are very often obstructed by dark-colored extractives. The axial parenchyma is often clearly visible, but sometimes it is less visible. As to the radial parenchyma, it is visible with a magnifying glass and is very characteristic. It can be uni, bi or multiseriate, while it uses to be uniseriate, as far as *Eucalyptus* trees are concerned. It is 2 or 3 cells wide; it is short and low. The fibers are short and have simple minute pits.



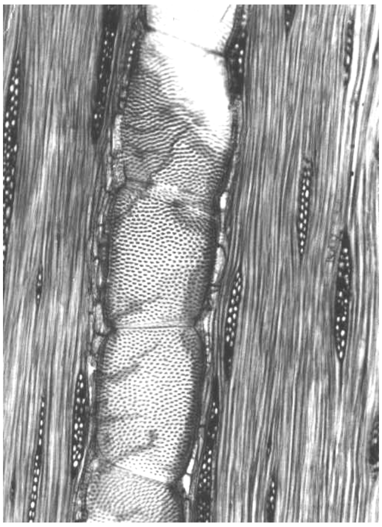
Block of *Acacia mearnsii* wood observed under an electronic microscope

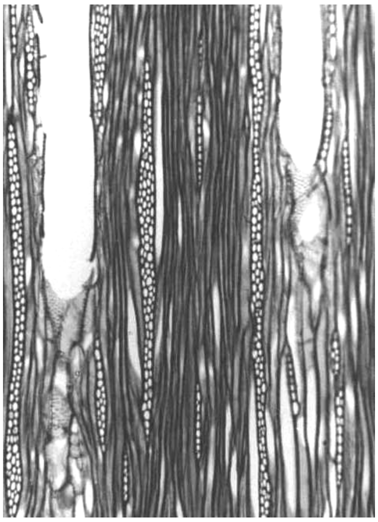


Cross sections of *Acacia mearnsii* wood



Cross sections of *Acacia mearnsii* wood

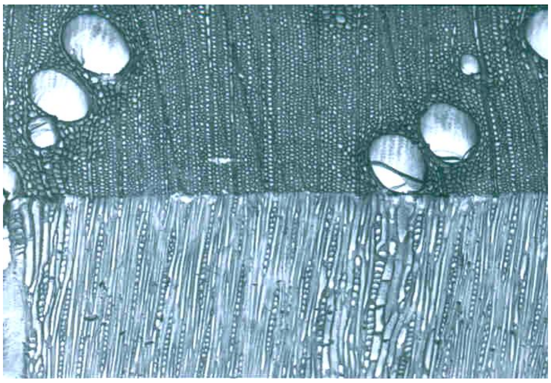


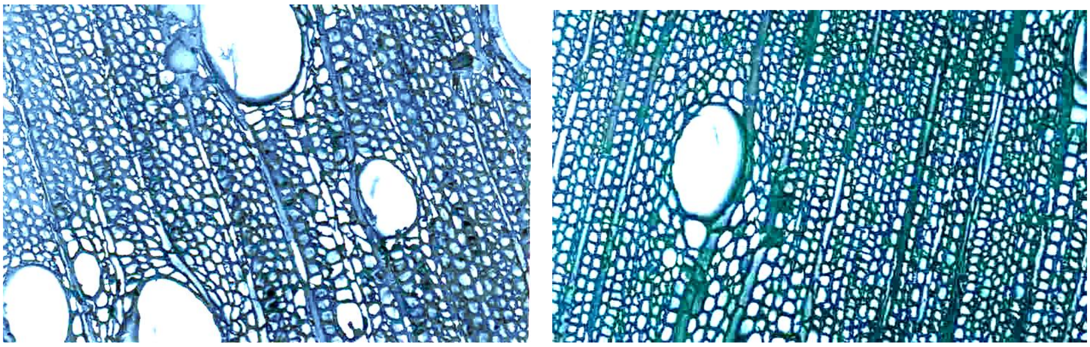


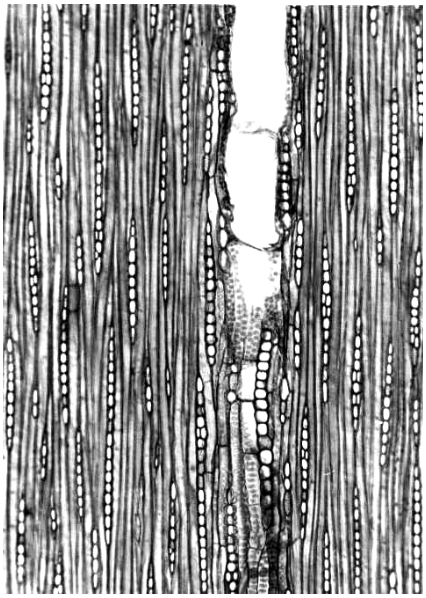
Longitudinal sections of *Acacia mearnsii* wood

- ***Eucalyptus* wood anatomy**

*Eucalyptus* trees present a very characteristic wood, the heartwood of which differs very much from its sapwood. The sapwood has a light chestnut coloring and is dense, while the heartwood has a reddish, rosy or yellowish color. The vessels are very well spread; they are large in diameter and visible with the naked eye. In most cases the vessels are isolated, some of them obstructed by extractives (tyloses). The radial parenchyma is scarce and almost invisible with the naked eye, and it uses to be vasicentric. The radial parenchyma is extremely thin; it is just one cell wide. The radial parenchymas use to be short, but they are very well distributed over the wood. The fibers are short and have simple and minute pits.


Block of *Eucalyptus saligna* wood observed under an electronic microscope


Cross sections of *Eucalyptus saligna* wood


Longitudinal section of *Eucalyptus saligna* wood

### • Xylem histometry

Histometry can be understood as the study of the proportional relationship and of the distribution among the various tissues composing an organ, which in our case is the wood or xylem. As far as *Eucalyptus saligna* and *Acacia mearnsii* woods are concerned, there are the following relationships between the anatomical constituents:

Table 02**: Xylem histometry** (Percentages based on volumes)

| | *Acacia mearnsii* | *Eucalyptus saligna* |
|---|---|---|
| Walls | 52 – 60 % | 50 – 55 % |
| Porosity (voids) | 40 – 48 % | 45 – 50 % |
| | | |
| Fibers | 60 – 70 % | 58 – 65 % |
| – Fiber walls | 40 – 45 % | 35 – 42 % |
| | | |
| Vessels | 15 – 18 % | 13 – 16 % |
| | | |
| Axial parenchyma | 10 – 12 % | 10 – 12 % |
| Radial parenchyma | 5 – 7 % | 10 – 13 % |
| Total parenchyma | 16 – 22 % | 22 – 25 % |

### • Fiber and vessel dimensions

Table 03**: Fiber dimensions**

| | *Acacia mearnsii* | *Eucalyptus saligna* |
|---|---|---|
| **Fibers** | | |
| ♦ Length, mm | 0.9 – 1.0 | 0.9 – 1.1 |
| ♦ Width or diameter, µm | 18 – 20 | 16 – 22 |
| ♦ Fiber wall thickness, µm | 4.2 – 5.5 | 3.2 – 4.2 |
| ♦ Wall fraction, % | 48 – 52 | 35 – 45 |
| ♦ Coefficient of flexibility, % | 48 – 50 | 55 – 60 |
| ♦ Runkel index | 0.9 – 1.1 | 0.7 – 0.8 |
| **Vessels** | | |
| ♦ Length, µm | 230 – 280 | 300 – 400 |
| ♦ Width or diameter, µm | 130 - 180 | 150 - 200 |

*Acacia mearnsii* wood fibers are very similar to those of *Eucalyptus* trees, for which reason they present similar papermaking performance, though with some differences, which we will report later on. Lengths and widths are close to each other; it is the wall thickness that differentiates them. *Acacia mearnsii* fiber walls are thicker than those of the fibers of *Eucalyptus* papermaking species are. For this reason, each black wattle fiber is heavier than a corresponding fiber of the commercial *Eucalyptus* used for pulp and paper production in Brazil. This will impart a distinct behavior to the *Acacia mearnsii* pulp. However, it should be clear that wall thicknesses of the same level as that found for *Acacia mearnsii* exist for many *Eucalyptus* species and even for *E.saligna* and *E.urograndis* trees of older forest stands.

Significant differences between these woods are their histometry and the tissue distribution over the wood. Although the proportion of vessel volume is rather similar in acacia and *Eucalyptus* woods, just a little higher for the black wattle; the acacia vessel elements are shorter and smaller in diameter, so that they are much more numerous in the woods and corresponding pulps.

Besides the number of vessel elements per gram of wood or pulp, the acacia vessels in the wood are in general geminate, while those of *Eucalyptus* are isolated. For this reason, the vessel distribution over the cross section of *Eucalyptus* wood is better than in black wattle wood. Another differential factor is the proportion of radial parenchyma, which is lower in black wattle woods. Also the spatial distribution of these radial parenchymas is worse in black wattle woods.

Just to remind: comparatively to *Eucalyptus* woods oriented to papermaking, the black wattle wood has:

- a higher proportion of cell walls (the wall fraction is higher for black wattle fibers),
- more concentrated vessels and less dispersed in the wood,
- a lower proportion of radial parenchyma,
- these radial parenchymas are also thicker and worse distributed over the longitudinal section of the wood,
- the fibers present a smaller lumen diameter and thicker walls.

These characteristics combined with the higher basic density of *Acacia mearnsii* wood result in greater difficulties for the impregnation of the wood chips, with both water and cooking liquors for pulp manufacturing, or else with wood preservation materials. The ray parenchyma and the vessels facilitate liquid penetration into the wood. In the case of *Acacia mearnsii*, they are arranged more distantly from each other, as compared to the *Eucalyptus* woods. Hence the liquid impregnation and penetration difficulties for the acacia wood.

In addition to this, the denser woods and in logs smaller in diameter tend to result in thicker chips and in higher proportion of slivers. These are additional chip preparation problems, which must be very well understood by the personnel producing chips for pulp manufacturing. If chips for burning as biomass are concerned, this is no problem at all; on the contrary, the higher density is even an excellent advantage. But for pulp production this is not the case. The proper wood chipper adjustments and chip dimensions selection are vital for the case of using this wood for pulp manufacturing.

The cooking or pulping processes require good wood impregnation by the cooking liquors. This impregnation is associated with chip thickness and overall dimensions, as well as with the vessel element and radial parenchyma contents and distributions.

Then it becomes clear that the black wattle wood is less accessible for liquid penetration than the most usual pulp manufacturing *Eucalyptus* woods (those of medium basic density, such as *E.saligna, E.grandis, E.urograndis, E.urophylla, E.dunnii, E.nitens*). This point must be understood and worked on by those using *Acacia mearnsii* wood for purposes where liquid impregnation is the industrial process basic concept.

Suitably dimensioned kraft pulp production wood chips

- **Chemical wood composition**

The *Acacia mearnsii* wood is renowned because a lower lignin and a higher hemicellulose content as compared to most *Eucalyptus* species. This is rather favorable for pulp production by whichever converting processes. However, it is less favorable for energy generation, as it will be seen later on.

The literature contains many comparative chemical evaluations between *Eucalyptus* and black wattle woods. Table 04 shows a synthesis of these chemical composition data concerning black wattle wood as compared to those regarding the most usual *Eucalyptus* for industrial use in Brazil.

Table 04**: Chemical wood composition**

| **Chemical analysis** | ***Acacia mearnsii*** | ***E.saligna*** | ***E.grandis*** |
|---|---|---|---|
| **Solubility in %** | | | |
| ♦ Cold water | 1.3 – 1.9 | 0.7 – 1.6 | 0.9 – 1.3 |
| ♦ Hot water | 2.0 – 3.3 | 1.5 – 2.9 | 2.0 – 2.5 |
| ♦ Hot 1% NaOH | 14.8 – 17.3 | 10.4 – 13.5 | 11.5 – 12.5 |
| ♦ 5% NaOH at 20ºC | 14.7 | 8.0 | 7.0 – 9.0 |
| ♦ 8% NaOH at 20ºC | 13.8 | 7.9 | 6.9 – 7.8 |
| ♦ Alcohol benzene | 1.8 – 2.7 | 1.0 – 1.9 | 1.4 – 2.5 |
| ♦ Dichlormethane | 0.3 – 0.4 | 0.3 – 0.6 | 0.4 – 0.7 |
| **Contents of (%)** | | | |
| ♦ Pentosan | 20.4 – 21.3 | 14.0 – 14.4 | 14.5 |
| ♦ Holocellulose | 80.3 – 81.5 | 74.0 – 75.3 | 76.5 |
| ♦ Lignin | 18.8 – 19.6 | 25.7 – 26.8 | 25.0 – 27.0 |
| ♦ Ashes | 0.2 – 0.3 | 0.2 – 0.3 | 0.2 – 0.35 |
| **Mineral contents (ppm)** | | | |
| ♦ Potassium | 860 | 700 | 820 |
| ♦ Calcium | 850 | 520 | 540 |
| ♦ Magnesium | 260 | 190 | 180 |
| ♦ Sodium | 360 | 460 | 240 |
| ♦ Aluminum | 70 | 155 | 55 |
| ♦ Manganese | 9 | 15 | 17 |
| ♦ Silicon | 7 | 25 | 13 |
| ♦ Iron | 2.3 | 5 | 3.5 |
| ♦ Copper | 1.3 | 1.4 | 1.1 |
| ♦ Nickel | 0.06 | 0.3 | 0.15 |

The black wattle wood presents characteristics, which are rather different from those of the most usual *Eucalyptus* for industrial use in Brazil. Significant are the differences in hemicellulose content (higher), in caustic soda solubility (higher), in lignin content (lower), in the extractives contents (higher) and in the micro-nutrient mineral contents (lower).

The higher caustic soda solubility results from the higher hemicellulose content. The higher extractive contents are possibly a reflection of tanning substances and gums; the last caused by the phytosanitary aspects of the trees.

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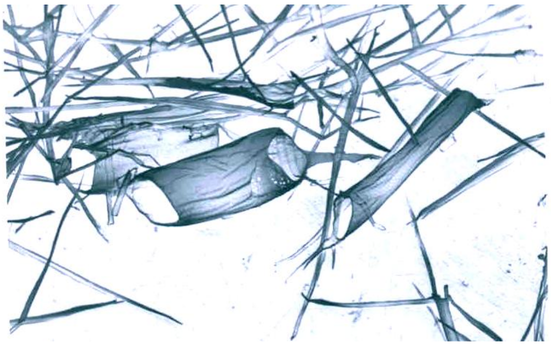
## USE OF *Acacia mearnsii* WOOD FOR PULP AND PAPER MANUFACTURING

Fibers and vessel elements in *Acacia mearnsii* pulp



Fibers and vessel elements in *Eucalyptus* pulp

The main factors to be managed in acacia pulp production are as follows:

- To have adjusted log chippers, suitable for the dimensions of these thinner black wattle logs;
- To suit chipper operation and adjustments to the higher black wattle wood density;
- To maintain an efficient control of chip dimensions (thickness, proportion of slivers and overthick chips);
- To guarantee chip impregnation by the cooking liquor, so as to have suitable liquor penetration and diffusion: to have a low-temperature pre-impregnator is vital;
- To maintain an efficient control of shives and rejects in the pulp after cooking;
- To work at slightly lower cooking temperatures and longer times, in order to avoid hemicellulose degradation and thus the resulting yield loss at conversion;

♦ To maintain an efficient control of extractives in the process, in order to avoid gum and pitch deposition on the equipment and pulps.

The higher wood solubility rates indicate that the alkaline processes must be very well applied, in order to guarantee hemicellulose re-precipitation and re-deposition on the fibers. If this is not done, pulp yield will decrease, as a significant fraction of the dissolved hemicelluloses will be directed to the recovery cycle as organic matter in the black liquor. It should not be forgotten that just a lower lignin content in the wood is no guarantee of better pulp production yields. In case impregnation is bad, the reject content will considerably increase and the amount of screened pulp will be smaller. Furthermore, if the hemicelluloses are too much degraded at cooking or bleaching, yield will also drop and the advantage of the smaller lignin content will be lost.

## • ***Acacia mearnsii*** **wood processing to kraft pulp**

The black wattle kraft pulp is already a well-known reality in Brazil. For many years this wood was used by Riocell S/A, in the State of Rio Grande do Sul, both in mixtures with *Eucalyptus* and in the form of pulp runs composed of 100% acacia wood, under demand. Despite the limitations that the company had at that time in terms of chippers and digester, dating these technologies from the seventies, the black wattle wood was always considered to be an excellent source of fibers. The most usual black wattle proportions in the wood blends ranged from 10 to 50% in the chip volume fed to the Riocell digester. Nevertheless, the basic density of the black wattle wood is on average 0.6 $g/cm^3$ (chip bulk density of 0.205 $bdt/m^3$), while that of *Eucalyptus* was 0.48 $g/cm^3$ (chip bulk density of 0.165 $bdt/m^3$). As a result of it, the proportions of acacia in the wood mixture on a weight basis ranged in fact from 12 to 55%. The most usually practiced mixture for conversion into kraft pulp was 25% in volume (30% dry weight basis).

The black wattle wood impregnation difficulties and its tendency to generate more rejects at kraft cooking were very well known. Chip quality and good impregnation are basic foundations for using this wood for kraft pulp manufacturing. In case this is not achieved, the advantages of lower lignin and higher hemicellulose content, offering yield gains in pulp production, end up getting lost.

This lower lignin content and possibly the quality of this lignin in terms of syringyl/guaiacyl ratio (unfortunately nothing was found about this S/G ratio in the literature) allow the generations of odorous compounds of methyl mercaptan and dimethylsulfide types at black wattle wood kraft and pre-hydrolysis kraft cooking to be lower than those obtained from

*Eucalyptus* woods: an interesting advantage in favor of the alkaline pulping of black wattle wood.

These characteristics of higher basic density of the wood (close to 0.6 g/cm³), of lower lignin content (about 20%) and of higher pentosan content (about 20%) cause this wood to be similar to that of *Eucalyptus globulus*. The fibers of these two species are relatively similar, in spite of a somewhat distinct papermaking performance behavior.

Knowing the black wattle wood limitations and having available some ways of optimizing chip impregnation and pulping, the following comparative data can be presented between the performances of *Acacia mearnsii* and *Eucalyptus* commercially used in Brazil for bleached kraft pulp production.

Table 05: **Usual values of conversion into kraft pulp**

| | ***Acacia mearnsii*** | ***Eucalyptus saligna*** |
|---|---|---|
| Solid wood volume in 1 stere | 0.6 | 0.68 |
| Basic wood density, g/cm³ | 0.6 | 0.5 |
| Dry weight of 1 st, bd kg/st | 360 | 340 |
| Screened kraft pulp yield in the digester (%) | 53.5 | 51.5 |
| Screened and unbleached bone dry pulp production (bd kg/st) | 192.6 | 175.1 |
| Specific wood consumption per bone dry ton of unbleached pulp, st/bdt | 5.19 | 5.71 |
| Specific consumption for production of one air dried ton of bleached market pulp, st/adt of bleached pulp[1] | 4.97 | 5.47 |

[1]Theoretical wood consumption, since the usual losses of the chip preparation area and the internal digester reject recycling, etc. are not computed. The same bleaching and bleached pulp screening yields have been admitted for both types of kraft pulps.

With regard to the chemical consumption for cooking and bleaching there are no significant differences to report. Furthermore, a mill designed to produce *Eucalyptus* kraft pulp can perfectly operate with black wattle wood, provided that the conditions to improve both chip quality and impregnation are observed. If this is not done, there will be additional quantities of ill-cooked knots at digester outlet and larger amounts of shives in the unbleached pulp to be screened.

This report can be summarized by mentioning the following black wattle wood advantages and disadvantages for kraft pulp production:

Black wattle wood disadvantages for kraft pulp production:

- Tendency to sliver and overthick chip generation at log chipping;
- Tendency to higher reject contents in the unbleached pulp due to the chip impregnation difficulties (wood anatomy and chip dimensions);
- Higher chemical reagent consumption in the digester when the chip dimensions are not suitable;
- Greater difficulties to obtain the desired degree of delignification (kappa number) under the conditions of excess of overthick chips and slivers. In such situations, approximately 1% more active alkali on wood basis and expressed as NaOH, as well as approximately 50 to 100 additional units in factor H are required. This does not occur when the chips present suitable dimensions.

Black wattle wood advantages for kraft pulp production:

- Higher screened pulp yields, approximately 2% more on wood basis;
- Higher unbleached pulp viscosity;
- Higher hemicellulose content of the pulp, expressed as hemicellulose content or as pulp solubility in NaOH. In terms of caustic soda solubility at 5% concentration, the values for the black wattle kraft pulps go as far as to be 40 to 50% higher than those of Brazilian commercial *Eucalyptus* trees.
- With regard to *E.globulus*, the situation is different, as the black wattle pulps and woods are more or less similar to those of the *E.globulus* species;
- Higher production per digester unit volume, which means that if white liquor and boiler capacity are available the mill may have its production increased when consuming acacia wood (either pure or in the mixture);
- Lower wood consumption, in both weight and volume, for production of one ton of kraft pulp.
- Potential increase in the daily mill production and reduction in manufacturing costs, things very much appreciated by pulp manufacturers.

- ***Acacia mearnsii* wood processing to neutral sulfite pulp - NSSC**

Although this NSSC pulp production is very marginal, it uses to occur at small mills operating in less competitive and traditional regions. The NSSC pulp presents high yield and uses to be bleached only with hydrogen peroxide. This pulp is used to manufacture packaging, printing and sanitary papers. There are mills having an associated lignosulfonate unit to produce this type of chemical, as otherwise the level of pollution would be unbearable. There are other companies sending the concentrated NSSC black liquor to neighboring kraft mills for burning, thus minimizing the environmental impacts.

The black wattle wood is rather viable for this processing, as it has a lower lignin content and its bleachability by the hydrogen peroxide is favored by the type of lignin and by the lower content of transition ions catalyzing hydrogen peroxide degrading reactions, such as manganese, nickel, and iron.

Table 06**: NSSC Pulps**

| | ***Acacia mearnsii*** | ***Eucalyptus saligna*** |
|---|---|---|
| Kappa number | 95 | 120 |
| Manganese content, ppm | 5 | 25 |
| Iron content, ppm | 15 | 30 |

- ***Acacia mearnsii* wood processing to pre-hydrolysis kraft pulp**

For many years the black wattle wood was used by Riocell S/A to produce pre-hydrolysis kraft pulp intended for manufacturing cellulose derivatives, such as viscose, cellulose acetate, rayon, cellophane, etc. In the same way as for kraft pulping, the conversion could be conducted with 100% of black wattle wood, 100% of *Eucalyptus* wood or blends between both of them.

There are many advantages in using black wattle by this process; the most significant being those connected with chemicals specific consumption and the acacia wood very simple processing. It is well known that when hemicelluloses are removed from wood by acid hydrolysis, we are weakening the bonding of lignin. Both wood chemicals are in the wood matrix as if the molecules of hemicelluloses and lignin were grafted onto each other. The previous removal of a large part of the hemicelluloses by (weak) acid hydrolysis allows a subsequent kraft cooking very easily. Without a great effort, kappa number values below 10 at digester outlet are reached even with caustic soda only.

The most usual pre-hydrolysis conditions reported in literature for *Acacia mearnsii* and *Eucalyptus* woods commercially viable for this type of pulp are as follows:

**Pre-hydrolysis phase:**
Temperature of 150 - 165ºC
Time to the maximum temperature: 90 minutes
Time at hydrolysis temperature: 60 minutes

**Kraft cooking phase:**
Temperature of 150° to 170ºC
Time at maximum temperature: 45 to 90 minutes
Active alkali: 21 to 23% NaOH basis, where sulfidity may range from 5 to 35% without any greater difficulties.

In the pre-hydrolysis kraft process, the hydrolysis phase aims to remove the hemicelluloses, which are undesirable in the pulps for cellulose derivatives (pulps for dissolution or dissolving pulps). When these hemicelluloses are (partially) removed, the residual lignin becomes topo-chemically more accessible and easier to be removed. The higher demand for active alkali in the kraft cooking phase is due to the acidity generated in the acid pre-hydrolysis phase.

Table 07**: Pre-hydrolysis kraft pulps**

| | *Acacia mearnsii* | *Eucalyptus saligna* |
|---|---|---|
| **Pre-hydrolysis phase** | | |
| • Wood basis yield, % | 77 | 82 |
| • Lignin in the pre-hydrolyzed wood, % | 22 | 29 |
| • Original wood basis lignin, % | 18 | 24 |
| **Kraft pulping phase** | | |
| • Pre-hydrolyzed wood basis yield, % | 48 | 42 |
| • Average total yield based on original wood, % | 38 | 35.5 |
| • Specific wood consumption (stere per bone dry ton of unbleached pulp at digester outlet), st/bdt | 7.35 | 8.30 |
| • Reject content in the unbleached pulp at digester outlet, % | 0.2 | 0.1 |
| • Kappa number | 9 | 11 |
| • Intrinsic viscosity, $cm^3/g$ | 950 | 850 |
| • Unbleached pulp brightness, % ISO | 43 | 40 |
| • $S_5$ – Solubility in NaOH at 5%, % | 1.8 – 2.5 | 1.3 – 2.0 |
| **General data** | | |
| • Specific wood consumption[1] (stere per air dried ton of bleached dissolving pulp), st/adt | 6.96 | 7.86 |
| • Bleached pulp brightness, % ISO | 90 - 92 | 90 - 92 |

[1]Theoretical wood consumption, since wood losses from the chip preparation area are not computed and internal digester reject recycling, etc., aren't either. The same yields have been admitted at bleaching and bleached pulp screening for both types of pre-hydrolysis kraft pulps.

Some of the black wattle wood advantages are also confirmed in this process, especially as to the specific wood consumption for producing one ton of bleached pulp considering all the industrial process. This may represent an increase in daily production and a decrease in manufacturing costs.

Also in this type of process, the mixtures of *Eucalyptus* with *Acacia mearnsii* woods are feasible and may even help control some specification parameters, such as intrinsic viscosity or residual hemicellulose content in the final bleached pulp.

### • *Acacia mearnsii* kraft pulp bleachability

Suitable cooking is required to guarantee good pulp bleachability and to achieve good final product cleanliness and brightness. This point is reinforcing once more the demands for good quality chips, as far as dimensions are concerned. A great black wattle pulp advantage is its easy drainability, because of which it can be washed rather easily. This is a result of its lower fibrous population. As a result of it, along the bleaching process the consumption of bleaching chemicals can be lower, as the pulp is better washed after each stage and can be also brought to higher consistencies. Thus the bleaching chemical and COD carry-overs are minimized. COD is the Chemical Oxygen Demand, giving an indication of the organic matter present in the filtrates.

High caustic soda dosages should be avoided in the alkaline stages of the bleaching process, as well as at oxygen delignification, in order to prevent hemicelluloses from being removed, a common occurrence if no care is taken to avoid it.

When the chips are irregular, a higher shive content is generated, which ends up impairing the bleaching and screening operations, or requires more attention to be paid to them.

Other points deserving care are as follows: the control of extractives and of the potential of pitch deposition; the hexenuronic acid generation and the respective role in pulp bleaching. Due to this hexenuronic acid generation at kraft cooking, the hemicellulose rich pulps may require additional chemical consumption be for bleaching.

Under normal and suitable processing conditions, the acacia pulps or those obtained from *Eucalyptus* and acacia wood mixtures do not present any differences with regard to *Eucalyptus* pulps to be bleached to the levels of brightness required for market pulps.

## • The *Acacia mearnsii* pulp fibers in comparison to those of *Eucalyptus*

The black wattle papermaking fibers are rather typical, as they have lengths and widths similar to those of *Eucalyptus* woods, but thicker cell walls. As a result of it, each black wattle fiber is heavier than a corresponding *Eucalyptus* fiber. As a consequence, the fibrous population in number of fibers per gram is lower for the black wattle pulps, whereas fiber coarseness is higher. It can be said that these properties are more similar to those of *Eucalyptus globulus* and other *Eucalyptus* pulps, but of older trees (cases of denser *Eucalyptus* woods).

Fibers with these characteristics are interesting for some paper grades, such as tissue, decorative, filtering and absorbing papers. Also, they are welcome where good formation and high drainability and dewatering on the paper machine, as well as higher porosity, are desired. However, a lower fibrous population leads to lower opacity values in the printing paper sheets.

Besides the fibers dimensions, these acacia pulps present another fundamental characteristic, which is the higher hemicellulose content with regard to Brazilian *Eucalyptus*, but not so different as compared to the Portuguese *Eucalyptus globulus*.

Fiber dimensions and hemicellulose content impart very typical properties to the black wattle papermaking fibers. They are rigid when unrefined. However, as they have many hemicelluloses in their composition, they are more easily collapsed during stock refining than the *Eucalyptus* fibers normally used in Brazil. Even so, it is difficult for them to gain strength at the beginning of refining, resisting the rise in terms of Schopper Riegler degrees. This is a further advantage for manufacturing tissue papers, which do not appreciate pulps with high bonding capacity. On the other hand, they easily lose the high bulk they have in unrefined pulp sheets, since the fibers collapse easily.

There are other important and differentiated characteristics in *Acacia mearnsii* kraft pulps some of them favorable and other ones unfavorable, as it always uses to be.

Unfavorable is the higher vessel element content presented by these black wattle pulps, which interferes with their paper sheet printing, thus aggravating the vessel picking problem if no suitable measures are taken by the papermaker and by the printer. Furthermore, cases of increased presence of "dust" in the paper due to this higher vessel element content are also reported.

Favorable characteristics are:

- The slightly lower fine content in the acacia pulps (lower proportion of parenchymas);

- The lower water retention value (favoring fiber drainage and dewatering at paper machine wet end, as well as the higher web consistency at dryer section inlet, allowing lower steam consumption or an increase in paper machine speed). There are papermakers reporting steam consumption savings between 8 and 12% due to the increase in consistency of the web manufactured with black wattle pulp after the wet press section. As consistency is also higher after the Fourdrinier, the web break occurrences are also minimized. All these aspects are excellent for the papermakers.

It is very important for us to know these differences, so that we can value the advantages and understand the disadvantages and the difficulties of the papermakers using these pulps. It should be remembered that it is rather human to complain about disadvantages and to take the advantages for granted. Hence the good technical argumentation and the good knowledge required for manufacturers of kraft pulp and papers from black wattle, whether it is used in pure state or in mixtures with other fibers.

Table 08**: Fundamental pulp and fiber properties**

| | ***Acacia mearnsii*** | ***Eucalyptus spp.*** |
|---|---|---|
| $S_5$ – Solubility in caustic soda at 5 %, % | 15 - 17 | 9 - 12 |
| Fine content, dynamic drainage jar test, % | 5.0 – 6.5 | 5.5 – 7.0 |
| Coarseness, mg/100 meters | 8.0 – 11.0 | 5.5 – 8.5 |
| Number of fibers per oven dry gram of pulp | 15 – 19 millions | 19 – 25 millions |
| Number of vessel elements per oven dry gram of pulp | 100 to 140 thousand | 60 to 100 thousand |
| WRV – Water Retention Value of dry market pulp, % | 90 - 100 | 110 - 125 |

- **Refining of *Acacia mearnsii* pulps and their papermaking uses**

The fundamental black wattle fiber characteristics, as discussed in the previous section, affect and differentiate their behavior in the paper manufacturing processes and in the properties of their papers.

It was already seen that, as far as their properties are concerned, the acacia fibers seem to be more indicated for tissue type and absorbing papers and less indicated for printing papers. However, with suitable preparation, these black wattle pulps can be good raw materials for these and other paper grades, such as decorative, filter, cigarette, packaging papers, multi-layer boards, etc.

As the fibrous population is lower in black wattle pulp than in most *Eucalyptus* pulps, its drainability in unrefined condition is fast. For this reason, its Schopper Riegler degree is low and takes a longer time to increase at the initial refining stage. It can be said that these pulps "resist the initial refining action". Moreover, as the fiber walls are thick, they consume energy to collapse and not so much to fibrillate. As a result of it, the sheets made from unrefined pulp are rather bulky and porous, but very weak. They are rather absorbing and present good opacity in this phase, without any refining. Unfortunately, the low fiber bonding of these unbeaten black wattle pulps does not contribute to good tear, tensile, burst, etc., strength values. With some refining, bulk gets lost due to fiber wall collapse, but the fiber bonding takes a certain time to be developed. The tear strength increases faster than the tensile and the burst strengths, which is good for tissue papers.

While it takes a longer time to change its degree of drainability, the strengths increase rather slowly. Nevertheless, porosity, bulk, opacity and water absorption losses occur more rapidly. This behavior is to be expected, since the pulp presents thick wall fibers and a high hemicellulose content in those thick walls. This imparts flexibility, plasticity and collapsibility to the fibers.

Also the vessel elements collapse easily as a result of refining and thus they are more retained in the sheet web structure. Their flattening contributes to the bulk, porosity and opacity losses.

The more difficult refining of these pulps manages to develop strengths in a slower rate, and it helps to impair interesting properties like porosity, bulk, opacity and water absorption.

It was already seen that this type of pulp presents advantages for tissue type paper grade manufacturing, where tensile development at refining is undesirable. As tissue machines are very fast and the paper web basis weight is extremely low (15 to 20 g/m²), the acacia pulps are very interesting because:

- They favor drainage and dewatering;
- They can be used almost unrefined;
- They do not develop tensile at the early stages of pulp beating, which would "close" the web, according to these papermakers;
- They have a lower content of fines to build up in the paper machine white water systems;
- They develop tear strength faster;
- They present suitable tear/tensile ratio in the initial refining phase (the higher the ratio, the better for this paper grade);
- They impart good smoothness and tactile softness to the tissue paper sheet.

It was already seen as well that the fundamental black wattle pulp characteristics might bring some disadvantages for printing and writing paper manufacturing, since these pulps show:

- Lower opacity,
- Lower strengths,
- Higher vessel element content,
- Greater difficulty to develop strengths with the refining process, which at last impairs both bulk and porosity.

In spite of these difficulties, there are pulp-refining technologies which help minimize them, so as to allow using successfully the black wattle pulps to manufacture those paper grades. Nowadays, with refiner discs that allow working at very low refining intensities, these problems are perfectly by-passed. It is important for the users to know well these differences with regard to other fibrous raw materials, in order to be able to suitably define their papermaking recipes or pulp stock blends.

As a final remark on this industrial black wattle wood utilization, it can be concluded that this wood can be perfectly recommended for good quality pulp and paper manufacturing. Acacia fibers can be used either in their pure form or in mixtures with other fibers, as for instance *Eucalyptus* fibers. We know that this mixture can be made either at the paper mill or at the pulp mill itself, when the latter chooses to produce pulp from mixtures of *Acacia mearnsii* chips with some other hardwood. In case of mixtures of *Eucalyptus* with black wattle, the industrial success was even already proven.

It cannot be said that black wattle kraft pulps are worse or better than the *Eucalyptus* ones. They are unique, in some aspects they present advantages and in other ones disadvantages. A good recommendation to the producers and to the users of these pulps is to search ways to maximize the positive and to minimize the negative points. The wood quality breeding and the industrial process improvements to be adequate to this raw material can help optimize this production chain. After all, their fibers are showing an attractive industrial performance in this production sector, even without having experienced any kind of forest improvement for such a utilization. As a result of a forest and industrial improvement program it can be anticipated that substantial gains may occur.

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## *Acacia mearnsii* UTILIZATION FOR BIOMASS FUEL PURPOSES


*Acacia mearnsii* charcoal

Acacia firewood burning in a power boiler

*Acacia mearnsii* wood and bark are good sources of energy and are very much consumed for both combustion and charcoal manufacturing.

The black wattle bark, after its extraction for tannin and tanning compound removal, loses about 25 to 35% of its dry weight as a function of this removal. Its volume changes little, due to the rigid structure represented by bark. Thus, the bark basic density, which was 0.42 to 0.45 $g/cm^3$, decreases to approximately 0.35 $g/cm^3$. Even so, it is an interesting raw material for energy generation, similar to the bark of *Eucalyptus* trees used for pulp production, the basic density of which ranges from 0.35 to 0.4 $g/cm^3$. Therefore, it is a good fuel biomass and may yield interesting calories in biomass boilers, especially when containing low moisture content (below 30% moisture).

The yearly production of black wattle bark in the State of Rio Grande do Sul has reached values ranging from 260,000 to 280,000 tons, as reported by the IBGE – Brazilian Institute for Geography and Statistics. This gross production is equivalent to approximately 12 to 14 tons of green bark per hectare, since about 20 to 25 thousand harvested hectares per year are concerned. As a function of the relationship between bark weight and wood volume produced, it can be estimated the yearly production of acacia wood in the State of Rio Grande do Sul to be something like 3.9 to 4.5 million steres of wood.

After tannin compound extraction the dry weight of the dry bark is reduced by approximately 25 - 35%. Even so, there remains an excellent supply for energy generation. As this bark had the tannin and a part of other soluble extractives removed, having also lost some of its mineral salts, the contents of lignin and carbohydrates on dry basis became even higher. For this reason, the calorific value of the dry acacia bark after tannin extraction continues to be attractive, above 3,400 kcal/oven dry kg. Then, it is its moisture content that will determine its energetic effectiveness.

Now, as far as black wattle wood is concerned, it consists in an excellent energetic biomass, both the "thin firewood", consisting of small diameter logs, and the well-known "black firewood" (defective wood due to the attack of the gummosis disease). A significant part of the wood from the acacia plantations of southern Brazil is sold as firewood to small undertakers, like those running such businesses as bakeries, pizzerias, potteries, grain and tobacco leaves drying. Another portion of this firewood is very popular with the society of the State of Rio Grande do Sul, feeding firewood stoves, fireplaces and barbecue appliances. There is still a significant part of acacia wood feeding biomass boilers in the form of logs or chips. Therefore, the acacia plays an important role in generating heat, steam and electric power in the State of Rio Grande do Sul. It also generates happiness and comfort in many homes of that state.

The black wattle wood is dense, in general denser than the wood of most *Eucalyptus* commercially planted in Brazil (*Eucalyptus grandis, E.saligna, E.urograndis, E.dunnii, E.viminalis, E.robusta, E.urophylla*, etc.). Nevertheless, its lignin content, which is an advantage for pulp and paper production, means in this case a disadvantage.

It is well known that the calorific value of an organic biomass fuel is strongly associated with its percent content of carbon on a dry weight basis. As lignin is carbon richer than cellulose and the hemicelluloses, the higher the lignin content of a biomass, the higher its calorific value. This can be understood by the simplified molecular formulae of these wood constituents.

Cellulose: $(C_6H_{10}O_5)_n$ ............... Molecular carbon content = 44.5%

Hemicellulose (xylan): $(C_5H_8O_4)_n$ ... Molecular carbon content = 45.5%

Lignin: $C_{40}H_{44}O_6$ ........................... Molecular carbon content = 77.5%

As far as *Eucalyptus spp.* and *Acacia mearnsii* woods are concerned, there is a significant difference in their chemical constitutions, as already seen in a previous section of this book chapter. As a function of these differences and of the relative proportion of carbon in those different constituents, the black wattle wood contains in general about 2 to 2.5% less carbon than the standard *Eucalyptus* wood, which is much richer in lignin.

As a rule of thumb, each 1% of elemental carbon in the dry biomass constitution results in approximately 100 kcal/dry kg of the biomass. For this reason, the black wattle wood has a potential to generate 200 to 250 kcal/dry kg less than the *Eucalyptus* wood, as a function of its lower lignin content and consequently of the constituent carbon.

- Superior calorific or heating value:

*Acacia mearnsii*: 4,200 to 4,350 kcal/dry kg

*Eucalyptus spp.:* 4,400 to 4,600 kcal/dry kg

However, a biomass does not live only on the basis of the calorific value. The black wattle wood presents some important advantages for its use as biomass. It contains lower moisture when felling the tree, it dries faster and it has higher wood basic density. As a consequence, the black wattle firewood is very attractive and demanded by the energetic biomass purchasers. The higher basic density ends up compensating for the lower carbon content. After all, per stere of wood (or cubic meter of stacked wood), the energetic generation is similar and even favorable to the acacia, as compared to the *Eucalyptus* most frequently found on the market as biomass.

- Energetic potential of bone dry woods (stacked wood logs)

It should become very clear that the data presented in the following would be the maximum potentials in terms of energy of these biomasses, since they are based on the dry wood calorific values (superior power values). We are presenting them just in order to show the energetic differences between these woods. In practical life, we must work with the inferior calorific values, which the energy lost with the water released at combustion, as well as the energy lost due to the wood moisture, must be deducted from. We will see much more about all this in the chapter we will write soon about biomass fuels.

***Eucalyptus grandis***: 300 to 320 dry kg/stere of wood
Approx. 1.4 Gcal/stere

***Eucalyptus saligna***: 320 to 340 dry kg/stere of wood
Approx. 1.5 Gcal/stere

**Eucalyptus urograndis:** 350 to 360 dry kg/stere of wood
Approx. 1.6 Gcal/stere

**Eucalyptus paniculata:** 410 to 430 dry kg/stere of wood
Approx. 1.9 Gcal/stere

***Acacia mearnsii***: 350 to 370 dry kg/stere of wood
Approx. 1.55 Gcal/stere

For energetic biomass, in the form of wood chips, the situation becomes even more favorable for the black wattle, as compared to the most common *Eucalyptus* woods available on the market as biomass fuel.

- Energetic potential of bone dry woods (wood chips)

***Eucalyptus grandis***: 145 to 150 dry kg/m³ of chips
Approx. 0.65 to 0.68 Gcal/m³ of chips

***Eucalyptus saligna***: 155 to 170 dry kg/m³ of chips
Approx. 0.70 to 0.75 Gcal/m³ of chips

**Eucalyptus urograndis:** 165 to 180 dry kg/m³ of chips
Approx. 0.75 to 0.78 Gcal/m³ of chips

**Eucalyptus paniculata:** 210 to 220 dry kg/m³ of chips
Approx. 0.95 to 0.98 Gcal/m³ of chips

***Acacia mearnsii***: 185 to 210 dry kg/m³ of chips
Approx. 0.80 to 0.90 Gcal/m³ of chips

Furthermore, black wattle wood has thinner logs, easier to handle by the small rural landowners or the businesses where it is necessary as firewood. Hence the enormous sympathy existing in the State of Rio Grande do Sul for the acacia firewood.

For conversion into charcoal the acacia is also considerably demanded. The most usual carbonization is of the lower part of the tree that was attacked by gummosis, where the logs are larger in diameter and often have the bark still present. This wood is extractive rich and has high basic density. Considering these characteristics, the black wattle charcoal is rich in calories, about 7,400 to 7,500 kcal/dry kg and has also a high fixed carbon content (approximately 77 to 80%). Other important advantages are: high apparent density (0.35 to 0.37 g/cm³ in the solid coal), high bulk density of the coal (210 to 220 kg of coal per cubic meter of heaped coal) and low ash content in the coal (0.3 to 0.5%). These densities are approximately 15 to 20% higher than the coal densities of the most usual *Eucalyptus* species. Another very appreciated black wattle coal advantage is its low friability: it does not crumble very much, it is rather consistent, and it generates little dust, debris and fines (coal chaff).

For all these reasons, the black wattle charcoal is very popular in Rio Grande do Sul, so that it is almost always the preferred one when it comes to roast a good barbecue. Everybody believes that the black wattle coal generates more heat, lasts longer as burning coal and ennobles the barbecue and gives a certain comfort to the roaster. The same applies to the industrial use of acacia charcoal by the local steel manufacturing industry.

In case it is desired to produce higher quality *Eucalyptus* coal, even with some advantages with regard to the black wattle one, species suitable for this purpose should be sought for. It is the case of the species of *Eucalyptus* and *Corymbia* genera, which have high and uniform basic density woods: *Eucalyptus paniculata, E. tereticornis, E.cloeziana, Corymbia citriodora* and *C.maculata.* In some situations in the State of Rio Grande do Sul, some of these species are used for coal production.

The State of Rio Grande do Sul has approximately 30,000 small producers of charcoal from *Eucalyptus* and black wattle woods. However, the charcoal production in that state is small as compared to the Brazilian production as a whole, led by the State of Minas Gerais. RS has about 1.6% of the Brazilian production, which amounts to the grand total of 2.5 million tons in the country.

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## SYMBIOTIC PROCESSES WITH *Acacia mearnsii*

The *Acacia mearnsii*, as good *Leguminosae* as it should be, presents very important symbiotic processes, with both nitrifying bacteria and mycorrhizal fungi. The best-known and most important relationship is the symbiosis with the *Rhizobium*, a characteristic inherent in the *Leguminosae*. By this symbiosis, bacteria known as *Rhizobia* catch the nitrogen from the soil air and fix it in the form of soluble compounds which both bacteria and plants can consume later. Then this fixed nitrogen becomes a constituent part of the vegetable body of both bacteria and black wattle. When this organic matter mineralizes, this nitrogen is slowly released to the soils as available nutrient, enriching them.

The symbiont bacteria lodge in the black wattle thin roots, forming nodules and working there to help the black wattle supply on nitrogen. This phenomenon is referred to as nitrogen fixation because these bacteria catch the gaseous and inert nitrogen from the soil air phase and convert it into soluble products (ions) or amino acids and proteins (nitrogenated organic matter). The black wattle also does its part. It shelters these bacteria in its roots and provides moisture, as well as other kinds of nutrients. It is really a partnership orchestrated by Nature and which yields results, as both organisms do not live as parasites, but live peacefully and for their mutual benefit. The nitrogen fixation is frequent in *Mimosoideae* and *Papilionoideae* and less common in *Cesalpinioideae*.

There are also physical, chemical and biological soil factors, which can limit or favor the nodulation of the species forming this symbiosis.

The group of bacteria known as *Rhizobia* encompasses several genera: *Rhizobium, Bradyrhizobium, Azorhizobium, Sinorhizobium* and *Mesorhizobium*. This fixation allows even dispensing the nitrogenated fertilization in the cases where it effectively is needed. Thus, the environmental impacts are minimized due to lower fertilizer input requirements and the plantation initial costs are reduced.

The presence of nitrogen-fixing bacteria in black wattle soils is usual. Even so, it is interesting to promote inoculation of these bacteria already at the seedling preparation stage. The inoculum may originate from a laboratory (specialized strains of these bacteria): it is the best type of inoculum, as it is developed for this purpose. In case it is not available, an alternative is using soil from superficial ground of acacia plantations when preparing the seedling substrate. Another way of obtaining an inoculum is by preparing a black wattle thin root extract, by macerating these roots.

Inoculated seedlings have higher rooting and surviving capacity; they grow more vigorously and survive longer after planting.

Many studies confirm fixation of 150 to 250 kg of nitrogen per hectare per year by the nitrifying bacteria associated with the black wattle. This nitrogen is distributed among the parts of the acacia tree, preferably being stored in leaves and of course in roots, rather than in other parts. When harvesting the plantation, as it is 6 to 8 years old, there is in the aerial part of the plants an approximate amount of 300 to 450 kg of nitrogen per hectare. A great part of it is stored in the leaves. The export, as a result of removing the bark and the wood, is not so significant: then an approximate amount of 80 to 150 kg of nitrogen per hectare is removed. This means that after harvesting something around 200 to 300 kg of N/hectare is left from the aerial part for incorporation into the soil. However, there is also all nitrogen that was released or is being released by the organic tree litter deposited on the soil surface (litter fallen along the forest rotation). There is also the nitrogen present in the thick and thin roots. After all, it is a bank well supplied with nitrogen for these acacia plantation soils.

It is for all these reasons that it is much healthier in environmental terms to extend the forest rotation to a period of 6 to 8 years, not harvesting the plantation at younger ages. Furthermore, it is recommendable not to burn all vegetable residues from the forest harvesting (burning just that required to control the wood-boring beetle), as otherwise we will be throwing away most of this nitrogen that was donated to us by Nature.

Besides the symbiosis with *Rhizobium*, the acacias are capable of forming mutualistic associations with mycorrhizal fungi, which help to absorb nutrients and water, improving the quality of the root and the general nutrition of the plant. Some of the mycorrhizal fungi most commonly found in acacia plantations are *Pisolithus, Gigaspora, Glomus*, etc.

The sanity and productivity gains obtained with both kinds of symbiotic associations (*Rhizobia* and *Mycorrhizae*) reinforce the need to put into practice a previous seedling inoculation. This is fundamental when the new plantation is to be established in a soil that had no acacia planted in previously.

Further studies and researches are required to be able to optimize the processes and maximize the gains.

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## MIXED PLANTING OF *EUCALYPTUS* AND ACACIAS

Forest plantations involving more than one species are often considered by the environmentalists as preferable to the monocultures and still more to the clonal monocultures. As a matter of fact, it aggregates a little more biodiversity and complexity to the natural environment being used by man. In general, the forest planting companies do not look at this option with enthusiasm, as it means further costs, further controls, further planning, greater raw material variability and thus, greater variability in the forests and in the forest products. As most planted forest products are well-established commodities, such as pulp, paper, sawn wood, MDF type panels, etc., the purchasing markets may repel any alteration. There is always a need of good communication and strong persuasion of the purchasers to raw material changes. Despite these difficulties to persuade the planters of extensive forest areas to opt for mixed planting, this option exists. In the future, I'm sure it will play important role in forestry.

As a matter of fact, we got used to the clonal forests of low variability and low costs, where all trees have a replicate genome. The uniformity of growth and product quality is excellent. Nevertheless, in the Northern Hemisphere (Finland, Canada, Sweden, etc.) almost all forest-based industry relies on natural forests with multiple species. Both pulp production and that of many other forest-based products have relied on these mixed forests of greater biodiversity and greater irregularity. Therefore, it is not at all unheard-of or unusual to speak about mixed forests for the production of goods requiring wood as raw material.

On the other hand, the mixed plantations of *Eucalyptus* and *Leguminosae* present very interesting advantages. If in a first approach they are not enough to motivate the great producers of planted *Eucalyptus* forests, at least they may be useful for small and medium rural farmers planting small forest areas.

At present there are many research studies being conducted to evaluate planted forests with at least one *Eucalyptus* species and another one of a *Leguminosae* tree. The prospects, as it was to be expected, have been confirmed in almost all these researches. Among these expectations, the greatest one is the continuous supply of the vital nitrogen to the *Eucalyptus* on the part of the *Leguminosae*. As the thin roots of both types of vegetables interlace in the soil and as always a root renewal occurs, the *Eucalyptus* will always receive from the acacia, as a gift, a part of the nutrients that the latter is making available. Furthermore, the organic tree litter deposited on the soil surface enriches still more with nitrogen by the deposition of leaves and branches of the *Leguminosae*, which is nitrogen richer than the same parts of the *Eucalyptus*. As a result of this, the forest soil becomes nitrogen richer. But not only the *Eucalyptus* trees benefit therefrom. The *Leguminosae* gain in terms of mycorrhization, since the *Eucalyptus* present high capacity for associating with mycorrhizal fungi.

The results of these mixed plantations show that the forest growth rates of the *Eucalyptus* and *Leguminosae* trees are accelerated. The plants of both genera grow more vigorous and healthier. After all, nitrogen is vital for amino acid and protein formation and is required in the energy transfer processes in the plant metabolism.

There exist many studies of mixed plantations of *Eucalyptus* with *Acacia spp*., *Albizzia spp*. and even with bracatinga (*Mimosa scabrella*). All of them report higher nitrogen content in the aerial parts and in the roots of *Eucalyptus* trees with regard to the blank trials. Most studies also show that the final mixed forest production does not differ statistically from the 100% *Eucalyptus* blank stand production. On the other hand, wood production is much higher than the 100% *Leguminosae* blank stand production. Besides the nitrogen made better available for the plants, there occurs a better crown distribution, with greater sun penetration to reach the leaves. The *Leguminosae*, which presents a lower growth rate than the *Eucalyptus*, is forced to grow faster due to the competition. It manages to keep active and does not endure any choking or domination, as shown by the researchers. As to the *Eucalyptus* trees, they grow still more than their blank stands. In comparison with the *Leguminosae* trees, they may also be bigger and more productive. It is due to the greater growth of the *Eucalyptus* trees as compared to the own blanks that the mixed plantings are as productive as the pure *Eucalyptus* plantings.

There are different mixed planting combinations. The most usual ones consist in alternating 2 to 3 *Eucalyptus* lines with one *Leguminosae* line of trees. Another form consists in alternating narrow *Eucalyptus* tree belts and narrow *Leguminosae* tree belts in the same planting area.

I consider the mixed plantation alternative as an interesting possibility for the farmers, who will have more wood available and, moreover, will maintain the black wattle bark production. They will be able to thin the acacia trees at 7 years of age and to maintain the best *Eucalyptus* trees being managed for solid products (sawmill, etc.). With the acacia harvesting at 7 years of age, the remaining *Eucalyptus* trees will gain new forces to grow in volume, so much the more so as they will have the nitrogen rich acacia forest harvesting residues available in the nutrient cycling. This is wonderful, something deserving further studies and investigations on the part of companies and academies. There is much to be shown in terms of technical, economic, environmental and social feasibility for these tree associations in mixed-planted forests.

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## *Acacia mearnsii* AS AN INVASIVE PLANT

*Acacia mearnsii* has been classified as a forest species deserving special care as a function of its potential invasion of natural ecosystems. As its seeds are abundant and spread by the wind, ants and birds, there is always a possibility that black wattle plants might germinate in unsuitable places. This may occur in both agricultural crop cultivation and pastures and in areas of natural preservation. In spite of the dormancy of the seeds, they lose it at any small fire – hence the menace.

As a function of this, the black wattle plantations must be well planned and implemented so that there are protective systems against dissemination of its seeds (barriers to other plantations, agricultural crop cultivation, pastures, etc.). Furthermore, it is essential to monitor the invasion of natural ecosystems in order to eradicate the trees that will grow in unsuitable places.

Every black wattle forest plantation aside natural ecosystems like areas of permanent preservation and even legal reserve areas demands constant attention and monitoring of these natural ecosystems. The black wattle seedlings appearing in these ecosystems must be eradicated when they are still young. As the black wattle sprouts very badly, it is enough to cut the little plant in the transition region between stem and roots with a sickle or a hoe. The vegetable residues of the plant will aggregate organic matter and some nitrogen to the ecosystem, something that in the long run becomes a small benefit. When the acacia planter does not make this control, the plants invading these ecosystems can grow, blossom, fruit, seed and increase the invasion.

*Acacia mearnsii* plants "invading" an area of *Eucalyptus* managed for a sawmill

Black wattle plant “invading” a natural ecosystem

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## FINAL REMARKS

Definitively, there are fantastic opportunities for the black wattle and *Eucalyptus* to have interesting forest and industrial complements. It can be said that this is already occurring at present, but still in a rather incipient form. With more research and optimization in their forests, woods, processes and products, some mechanisms will be certainly found, by means of which these trees, instead of competing for soils and uses, may come to complement each other and to aggregate more environmental, social and economic quality to our Society, especially in Brazil, where there is already so much accumulated knowledge about them.

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## LITERATURE REFERENCES AND READING SUGGESTIONS

My friends, I have patiently panned out the literature in order to offer you a data bank easy to be accessed through the web. Approximately 160 references are listed in this section, covering much of the knowledge now-a-days available about *Acacia mearnsii* mostly in Brazil. I hope that those who will be also patient and will require this kind of information will be able to make good use of it. Navigate and amuse yourselves, there are remarkable things to be read and learned:


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