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Leucaena for paper industry in Gujarat, India: Case study

Leucaena para la industria de papel en Gujarat, India: Un estudio de caso

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Abstract

India is one of the major producers/consumers of paper and pulp products (3–4% of global share). Approximately one-fourth of industry raw material has come from wood-based plantations from the 1990s onwards. The greatest development challenge faced by the industry since that time is sourcing robust raw material from agroforestry on private lands. Following genetic improvement of leucaena (*Leucaena leucocephala*) and realization of its potential as a multiple-use species, it was introduced into India in 1980 under an international cooperation effort with support from the Swedish International Development Cooperation Agency (SIDA). It has since spread across the country as a panacea for rural needs of fuel wood, small timber and cattle forage. The paper industry has found that it has potential as raw material for paper making. One of the largest Indian paper companies is JK Paper Ltd, which has an annual production capacity of 550,000 t/yr with 3 integrated pulp and paper plants located at Songadh (Gujarat), Rayagada (Orissa) and Kagaznagar (Telangana) producing writing and printing paper and virgin packaging boards.

This case study describes the leucaena farm forestry plantation program initiated by JK Paper Ltd, Unit CPM (Central Pulp Mills). The unit, under its agroforestry and farm forestry plantation approach, planted leucaena plantations in 2009-2010 in parts of Gujarat, Maharashtra and Madhya Pradesh States. To motivate farmers in the mill's catchment area, and to build confidence in on-farm plantations, exposure visits were arranged to Andhra Pradesh, where huge tracts of agricultural land were under leucaena plantations. As a result, to date, this unit has engaged >7,800 farmers who have established leucaena plantations covering an area of >18,400 ha. A robust plantation R&D network addressed issues such as seed treatment, seed germination, rhizobial inoculation, geometry of plantations, agro-forestry models, selection and development of high production clones, establishment of clonal seed orchards, genetic improvement through mutation techniques and hybridization programs for wood quality improvement.

Keywords: Agroforestry, breeding, hybridization, mutation, plantations, pulpwood.

Resumen

India es uno de los principales productores/consumidores de productos de papel y de pulpa de papel (3–4% del total mundial). Desde la década de 1990 en adelante aproximadamente una cuarta parte de la materia prima para la industria de papel proviene de plantaciones de árboles maderables. El mayor desafío de desarrollo que enfrenta la industria de papel desde esa época es obtener fuentes sólidas de materia prima proveniente de agroforesterías establecidas en tierras privadas. Como consecuencia de las primeras actividades de mejoramiento genético y del reconocimiento de su alto potencial como especie de uso múltiple, se introdujo en 1980 la leucaena (*Leucaena leucocephala*) en India, en el marco de una cooperación con la Agencia Sueca de Cooperación Internacional para el Desarrollo (Swedish International Development Cooperation Agency, SIDA). Desde entonces se ha extendido por todo el país respondiendo como una panacea a las necesidades rurales respecto a leña, madera de dimensiones menores y forraje para ganado. La industria del papel encontró que la leucaena tiene potencial como materia prima para la fabricación de papel. Una de las compañías de papel más grandes de la India es JK Paper Ltd con una capacidad de producción de 550,000 t/año en 3 plantas

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integradas de pulpa y papel, ubicadas en Songadh (Gujarat), Rayagada (Orissa) y Kagaznagar (Telangana), produciendo papel para escribir e imprimir, y cartón de fibra virgen.

Este estudio de caso describe el programa de plantaciones agroforestales con leucaena iniciado por JK Paper Ltd, Unidad CPM (Central Pulp Mills). En el marco de un enfoque en plantaciones agroforestales y forestales, se establecieron plantaciones de leucaena en 2009-2010 en partes de los estados de Gujarat, Maharashtra y Madhya Pradesh. Para motivar a los agricultores en el área de influencia de Central Pulp Mills, y para crear confianza en el modelo de producción agroforestal, se organizaron visitas a Andhra Pradesh, donde existen grandes extensiones de tierras agrícolas con plantaciones de leucaena. Como resultado, hasta la fecha se ha involucrado a más de 7,800 agricultores quienes establecieron plantaciones de leucaena cubriendo un área total de más de 18,400 ha. Una sólida red de investigación y desarrollo abordó temas como el tratamiento de la semilla, su germinación, la inoculación con rizobios, la configuración de las plantaciones, los modelos agroforestales, la selección y el desarrollo de clones de alta producción, el establecimiento de bancos clonales para la producción de semillas, el mejoramiento genético mediante técnicas de mutación, y programas de hibridación para mejorar la calidad de la madera.

Palabras clave: Agroforestería, fitomejoramiento, hibridación, madera para pulpa de papel, mutación, plantaciones.

Introduction

JK Paper Ltd has an annual production capacity of 550,000 t/yr with 3 integrated pulp and paper plants located at Songadh (Gujarat), Rayagada (Orissa) and Kagaznagar (Telangana) producing writing and printing paper and virgin packaging boards. JK Paper Limited, Central Pulp Mills (CPM) Unit, is the largest integrated pulp producer in Gujarat with a paper and paperboard manufacturing unit located at Fort Songadh, Tapi District, Gujarat State, India, producing 155,000 t paper and paperboards annually. The annual wood requirement of CPM unit is about 275,000 t comprising primarily *Leucaena*, *Eucalyptus* and *Casuarina*, of which *Leucaena* is the major contributor (about 75%). To achieve a sustainable raw material supply, JK Paper Ltd has promoted social and farm forestry plantation programs in the mill's catchment area since 1996-1997. CPM unit provides quality seeds and improved clones at subsidized prices and provides free technical support to the farmers, including a guaranteed market for their harvested wood.

Plantation research and development and operational procedures

JK Paper Ltd, CPM unit, was originally based on using bamboo as raw material from leased forest areas from 1960 to 2006. During 2006, gregarious flowering in bamboo forests took place in south Gujarat forest areas, following which many bamboos died and productivity of bamboo was reduced from 100,000 to 20,000 t/yr. This led to a social and farm forestry plantation program promoting *Eucalyptus*, *Casuarina* and *Leucaena* species. A massive promotional drive to establish leucaena plantations was initiated from 2009 in Tapi, Surat, Navsari, Valsad, Bharuch, Narmada, Vadodara, Panchmahal, Anand, Kheda and Sabarkantha districts of Gujarat and Nandurbar, Dhule and Jalgaon districts of Maharashtra State. The program targeted mostly agricultural lands, farm bunds, arable waste areas and community lands (surplus land available with public sector units and state forest corporation lands for plantations under different agro- and farm forestry models). Initially direct sowing of seed was adopted for on-farm plantings, which was later slowly replaced by sowing of rooted seedlings of improved clones. For farm forestry, *Leucaena leucocephala* (K636 and K8 provenances) were planted and robust plantation R&D programs put in place to address issues of improving seed germination through chemical and mechanical treatment, and enhancing wood production through cloning of desired plant types. A hybridization program was initiated to enhance wood production plus disease and pest resistance. Mutation techniques were used to enhance wood production.

Following robust plantation research and development work, the CPM unit developed 40 different cultivars that were site-specific, disease-resistant and high-yielding from *Eucalyptus*, *Leucaena* and *Casuarina* species giving higher wood production (3–4 times more than from plantations planted with seed, and a shorter rotation age of 3 years). JK Paper Ltd, CPM unit, has about 18,400 ha of plantations in association with >7,800 farmers in Gujarat and Maharashtra States. CPM unit on-farm procedures are illustrated in Figures 1 and 2.

Figure 1a. Land preparation for leucaena plantations, showing drip irrigation lines.

Figure 1b. Sowing seed and using drip irrigation methods.

Figure 1c. Seed germination.

Figure 1d. Mechanized inter-row cultivation.

Figure 1e. Manual inter-row cultivation.

Figure 1f. 2.5-year-old mature leucaena plantations.

Figure 2a. Leucaena cuttings propagated in misting chambers.

Figure 2b. Two-year-old leucaena plantation at Surat.

Figure 2c. Leucaena with cotton intercropping.

Figure 2d. Leucaena with banana intercropping.

Extension and motivational efforts

A strong extension network involving local influential persons plus non-government (NGO) and Government agencies was established. Farmer meetings were organized to develop awareness among the farmers regarding the economic benefits available from pulpwood plantations. To instill confidence in this system we organized exposure visits to successful plantations in Andhra Pradesh, where an extensive area was covered with leucaena plantations, and to our mill and R&D Centre. Promotional stalls were established at different agricultural exhibitions in Gujarat and Maharashtra giving demonstrations regarding the economic and environmental benefits of plantations (Table 1).

Site preparation

Leucaena plantations were established within a 0–350 km radius of the mills in Gujarat and Maharashtra States. The majority of soils are black alkaline soils formed from basalt rock and the major agricultural crops are cotton, sugarcane, banana, papaya, black gram, green gram and *Cajanus cajan*. Deep ploughing with a mould-board plough followed by harrowing was recommended and organic manures such as cow dung were added prior to sowing. Most plantations are under a drip irrigation system.

Establishment procedures

Most farmers adopted tree spacings from the following range: 1.2 × 1.2 m, 1.5 × 1.0 m, 1.5 × 1.2 m and 1.0 × 3.0 m, which allowed intercropping in the first year. Seed was treated to ensure uniform and fast germination (70–80%), a critical factor in establishment of leucaena plantations. Methods for breaking leucaena seed dormancy included chemical treatment (99% H_2SO_4) and mechanical scarification with a Kimseed seed scarifier imported from Australia.

Seed is sown at the onset of the monsoon, i.e. in June-July, with 2 or 3 seeds per hole and irrigation is available at the time of sowing. Following germination, weeding is performed and leucaena plants thinned to 1 healthy seedling per location when they reach a height of 15–20 cm.

Table 1. Numbers of farmer meetings, farmer tours and visits to agricultural exhibitions.

Year	Farmer meetings at CPM		Farmer tours to Andhra Pradesh		Agricultural exhibitions	
	No. of meetings	No. of farmers	No. of tours	No. of farmers	Total	Total farmers (00,000)
2009/10	13	720	5	135		
2010/11	28	1,310	2	34		
2011/12	20	470			2	2.2
2012/13	78	715			3	0.1
2013/14	165	831			2	0.1
2014/15	129	305			2	0.1
2015/16	99	865			2	0.2
2016/17	57	570			1	0.1
2017/18	80	800			5	0.5
Total	669	6,586	7	169	17	3.3

The establishment cost of leucaena plantations is US$ 688/ha.

Rhizobia inoculation

Establishment of the rhizobium association proved to be sporadic. In order to enable faster growth, rhizobium cultures/colonies from different areas were tested with the help of M/s PAC Bio Fungbact Pvt Ltd, Madhi, Gujarat. It was found that a mixture of all rhizobia was best for helping development of profuse nodulation in seedlings (Figure 3). With the help of M/s PAC Fungbact Pvt Ltd, a rhizobium culture was developed in powder form and is being supplied to farmers along with seeds, where it is coated on seeds prior to sowing.

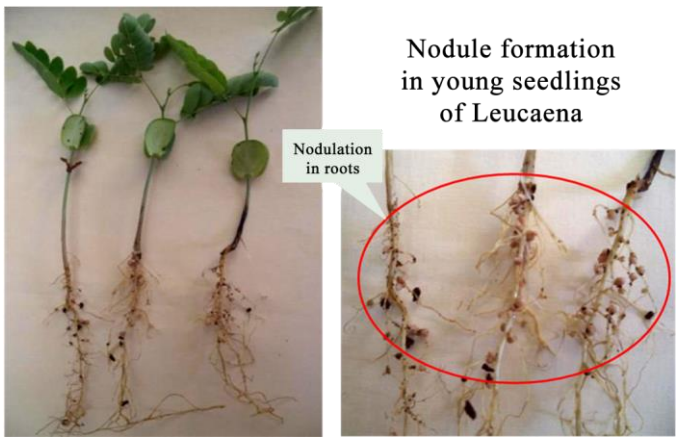

Figure 3. Rhizobial nodulation in leucaena.

Protection and maintenance of plantations

Where irrigation is available, it is applied every 15–30 days depending on soil moisture conditions. Fertilizer applications are based on soil testing and comprise 50 g NPK (12:32:16)/plant on 2 or 3 occasions for the first 2 years. In potash-deficient soils, an additional 50 g potash/plant is applied. Application of good quality organic manure is recommended, but no grazing, browsing or trampling is allowed. Termite damage is controlled by applications of 0.05–0.10% chlorpyriphos (5–10 mL/L of water) to soil around the base of the plant.

Agroforestry intercropping with leucaena

Intercropping of leucaena plantations in the first year is often practiced with cotton, ground nut, pigeon pea, green gram, bananas, onions, pigeon pea, chilli, castor oil, sugarcane or ginger. Farmers find that leucaena has no adverse effects on crop production in the first year. They report a range of benefits of intercropping, including:

- Higher returns/profits in comparison with normal agricultural crops, and reduced risk of crop failure;
- Nitrogen fixation by leucaena as a leguminous plant;
- Fodder for cattle feed;
- Fuel wood;
- Soil fertility improvement due to germination of fallen seeds that become bio-fertilizers;
- Humus formation by continuous fall of dead leaves;
- Pulpwood generation; and
- Environmental benefits due to carbon storage, reduced soil erosion and improved soil moisture retention.

Leucaena research and development

Productivity improvement through Candidate Plus Trees [CPTs]

In order to have a broader genetic base and to improve yield per unit area, a systemic genetic approach in research and development of leucaena is being under-taken. Selection of CPTs in Gujarat and Maharashtra

States at different sites is in progress. To date, about 1,300 CPTs have been selected. A further short list of the top 10 CPTs was selected for testing of pulping properties at our R&D laboratory. Screened pulp yields (pulp/fiber % of wood) varied from 47.2 to 51.4% (Table 2), slightly higher than the present average screened pulp yield of commercialized leucaena clones (about 47%). We have also collected coppice cuttings from these CPTs and have developed rooting methodologies in misting chambers.

Progeny testing for these CPTs is on-going. Initial results show that CPM 3, CPM 29 and CPM 32 have 125% growth compared with the control of existing leucaena field clonal plantations. Vegetative multiplication is on-going for further multi-location trials. Presently we are producing 6 leucaena clones and many more are in the pipeline to be released shortly.

Hybridization program in leucaena

In the first phase of this program, potential species used for crossing to produce hybrid vigor and higher pulp yield and wood production were *Leucaena collinsii* and *L. leucocephala* (CPM 11 and CPM 16 clones).

Leucaena collinsii, which is diploid (2n) with 52 chromosomes, was fast-growing and resistant to psyllids (*Heteropsylla cubana*) and grew up to 8–10 m in height in 2.5–3 years. It also produced less seed, resulting in faster vegetative growth.

The clones of *L. leucocephala*, which is a tetraploid (4n) with 104 chromosomes (Brewbaker 1988), were also fast-growing and grew up to 10–12 m in height in 2.5–3 years but were susceptible to the psyllid insect, resulting in loss of growth for 8–9 months in a 3-year rotation cycle. This species produced abundant seeds, resulting in less vegetative growth during seeding. *L. leucocephala* (CPM 16) was used as a male parent and *L. collinsii* as the female parent. About 100 flowers were emasculated for crossing and observed for maturity of their stigmas. The calyx was sprayed with IAA to avoid abscission of flowers during hybridization (Sorensson 1988), and all remaining flowers were removed. We produced 15 pods through this hybridization and subsequently grew seedlings in plastic containers from the seeds (Figure 4). A hybridization test carried out at JK Agrigenetics Ltd, Hyderabad confirmed that they were true hybrids (Figure 5). We planted progeny trials to study growth of the hybrids in the field. As *L. leucocephala* is tetraploid and *L. collinsii* is diploid, the hybrid is triploid and fully-sterile and hence must be multiplied from rooted cuttings. This work is on-going.

Table 2. Pulp quality, chemical consumption, pulp viscosity, pulp brightness, cooking condition for pulp yield for leucaena wood samples collected from 6 Candidate Plus Trees (CPTs).

Parameter	Clone/CPT											
	CPT 54		CPT 3		CPT 42		CPT 29		CPT 30		CPT 32	
Age of CPT (years)	3		3		3		1.5		1.5		1.25	
Cooking chemical[1] for pulping (AA) as Na_2O (%)	19	20	19	20	19	20	19	20	19	20	19	20
Pulping results												
Kappa no.[2]	17.5	16.9	17.3	16.6	16.5	15.6	16.9	16.4	16.0	15.5	15.9	15.3
Total pulp yield (% of BDMT[3] wood)	51.3	50.9	48.4	48.1	52.1	51.8	50.6	49.8	51.1	49.7	51.2	50.9
Reject (% of BDMT wood)	1.02	0.92	1.00	0.89	0.72	0.53	0.98	0.64	0.83	0.65	0.90	0.85
Screened pulp yield (% of BDMT wood)	50.3	50.0	47.4	47.2	51.4	51.3	49.6	49.2	50.3	49.0	50.3	50.0
Free alkali as Na_2O (g/L)	9.3	9.9	12.4	13.6	11.8	13.6	10.5	11.2	10.5	11.2	10.5	11.8
Brightness (%)	28.5	29.6	29.2	30.7	30.3	32.1	31.6	32.4	32.4	33.0	32.0	32.6
Viscosity (Cps)	16.5	15.3	16.8	15.0	16.2	15.2	16.8	15.0	16.3	15.0	16.6	15.1

[1]Cooking chemical for pulping (AA) as Na_2O (%) refers to % of white liquor required for cooking/pulping of wood chips in digester.
[2]Kappa number: an indication of the residual lignin content or bleachability of wood pulp by a standardized analysis method.
[3]BDMT = Bone dry metric tonne (= at 0% moisture).

Figure 4. Breeding of *L. leucocephala* and *L. collinsii.*

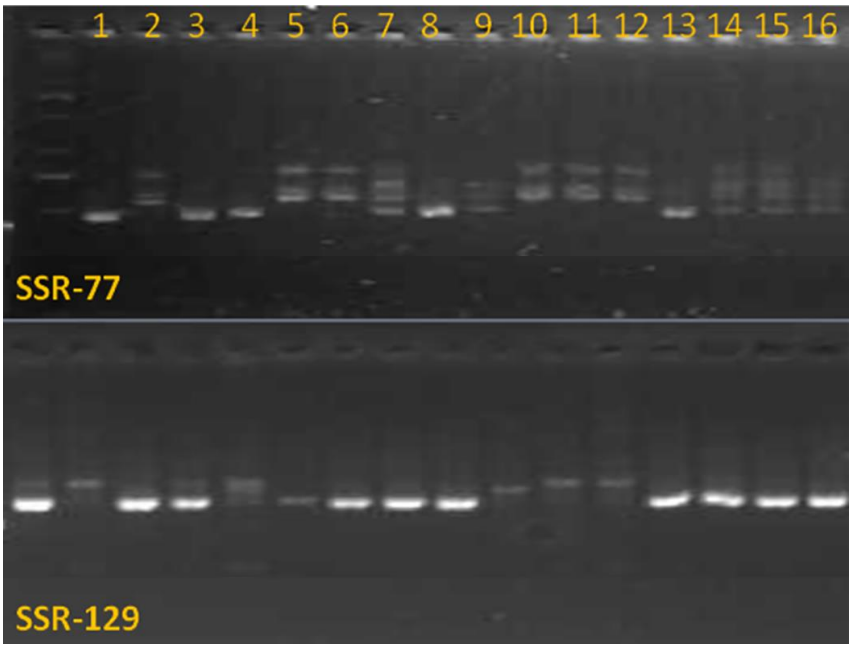

Figure 5. Leucaena samples- 1: K636 (mutated); 2: K636; 3: CPM 11 (mutated); 4: CPM 11; 5: CPM 16 (mutated); 6: *L. collinsii*; 7: CPM 16; 8: *L. collinsii* (mutated); 9: KX2; 10: CPT 32; 11: CPT 3; 12: CPT 29; 13: Hy 1; 14: Hy 2; 15: Hy 3; 16: Hy 4. Status of sample 6 (*L. collinsii*) - diploid; sample 7 (CPM 16) - tetraploid; samples 14, 15 and 16 - triploid – was confirmed as true hybrids by JK Agrigenetics.

Mutation techniques in leucaena

We used gamma ray mutation techniques for alteration of gene structure, which may transmit to coming generations. We irradiated leucaena seedlings of K636 (known as cv. Tarramba in Australia), *L. collinsii*, *L. leucocephala* clone CPM 11 and *L. leucocephala* clone CPM 16 with different frequencies of gamma rays at the nuclear research station, Indian Agriculture Research Institute, New Delhi and laid out progeny trials in August 2016 for studying the effects of mutations.

Based on the superior induced growth in some mutants, DNA fingerprinting analysis was carried out, which confirmed that mutations altered the gene structure and growth has been accelerated. Vegetative multiplication of positive mutants is on-going for further trials.

Clonal hedge garden techniques

A naturally ventilated polyhouse covered with 200 micron polythene stabilized against UV rays and provided with a fertigation system, plus temperature and humidity controllers, was constructed. Superior mother plants were planted in raised beds filled with pure sterilized sand at 10 × 10 cm spacing. Required fertilizer dosages were provided to the plants through the fertigation system and constant humidity and temperature were maintained. Every month about 3 or 4 juvenile coppice cuttings were obtained from each mother plant. The adequate nutritional status of the mother plants was important in increasing the rooting percentage of cuttings in the misting chamber.

Propagation techniques

Cocopeat was used for clonal propagation as it has low salinity as measured by electrical conductivity (EC). It also has excellent water holding capacity and cation exchange capacity. Fifty mL, 60 cell plastic root trainer blocks were used for production of clones (Lal 2001). Misting chambers with appropriate temperature and humidity control systems were installed over a 3,200 m^2 area at the clonal propagation centre in Songadh. Every month about 150,000 juvenile apical cuttings are established producing 1 million leucaena clones per annum. Water quality is critical for a successful misting chamber operation. Water used has a pH of 6.5–7.5, very low EC and sodium absorption ratio below 3. Reverse osmosis water rather than canal or river water is preferable for misting chamber operation (Brewbaker 1988).

Outcomes and discussion

Increased plantings

To date the CPM Unit has promoted the establishment of approximately 50,000 ha of social and farm forestry plantations in Gujarat and Maharashtra States (Figure 6) involving about 66,000 farmers. Similarly, 18,400 ha of leucaena plantations have been established by approximately 7,800 farmers (Figure 7).

Wood asset value of plantations

Wood generated from plantations promoted by JK Paper Ltd is being used for making paper, plywood, poles and furniture. The expected annual increase in value of wood is given in Figure 8. JK Paper Ltd, CPM unit plantation initiatives are creating sustainable livelihoods among nearby farmers by creating economical wood assets on their farm lands.

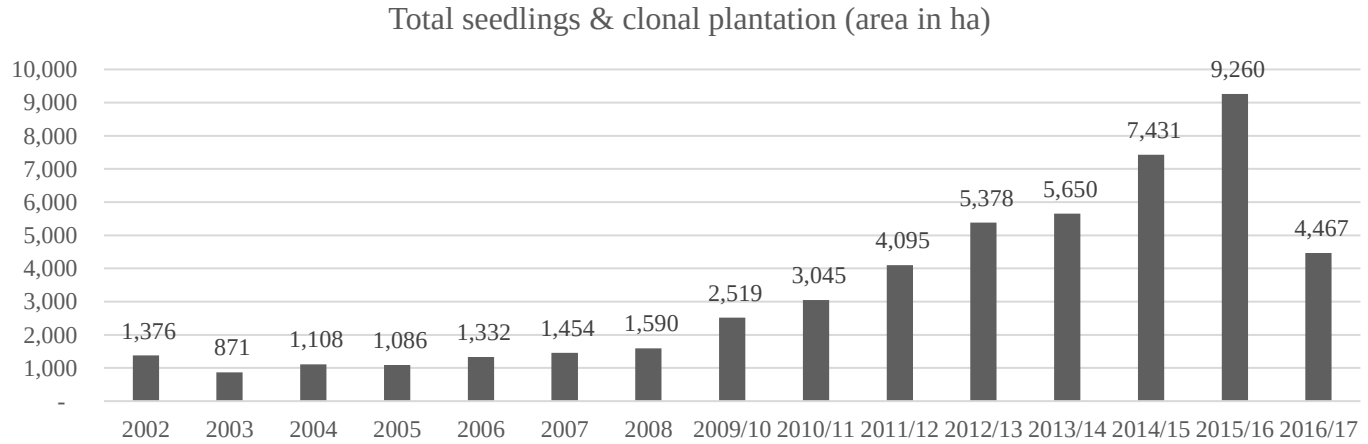

Figure 6. Annual increases in area under seedling and clonal plantations (ha). Note: The area planted in the year 2016/17 was low due to higher wood availability and lower wood requirement.

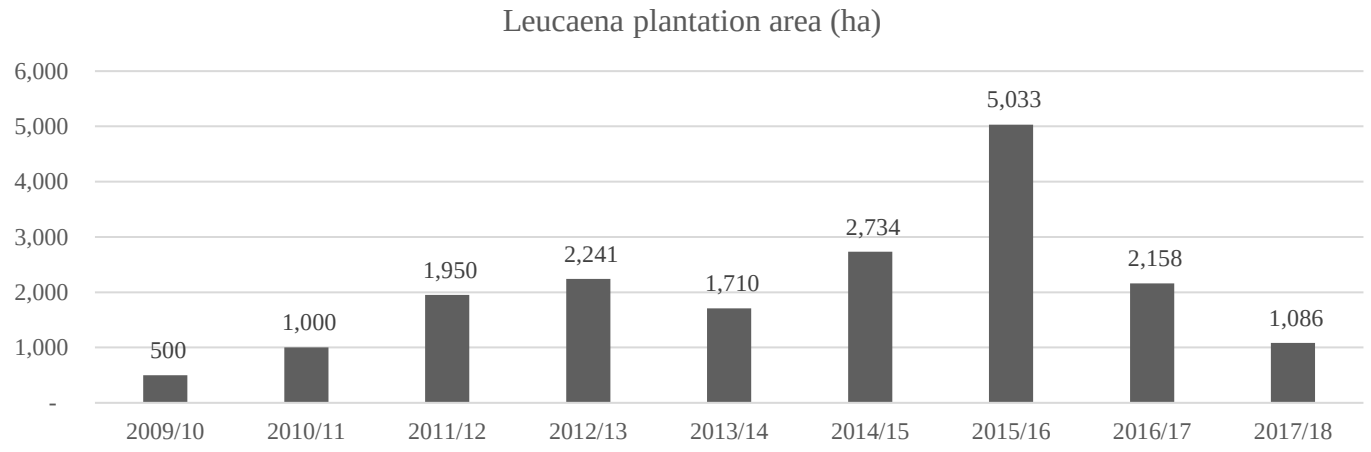

Figure 7. Annual increases in area under leucaena plantations (ha).

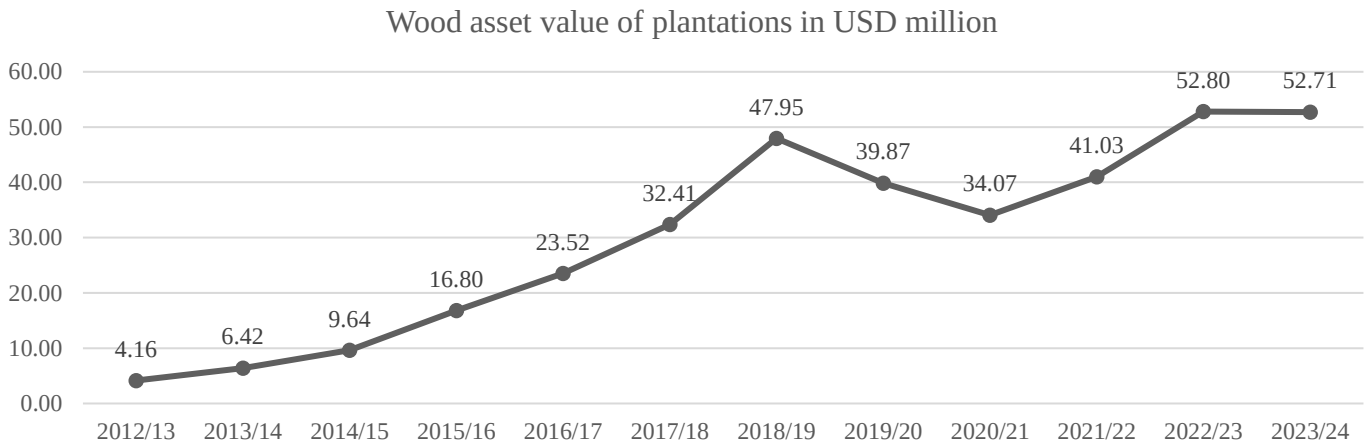

Figure 8. Estimated and projected wood asset value of plantations in millions of USD.

Survival, productivity and environment

Hi-tech clonal plantations in areas surrounding the mill have >90% survival. With continuous research and development efforts, site-specific, disease-resistant, fast-growing and high-yielding clones achieved a productivity of 30–50 t/ha/yr.

The value of JK Paper Ltd farm forestry program is immense in mitigating environmental degradation. Apart from increasing greenery and tree cover, farm forestry has significant potential for carbon storage. Estimated quantities of CO_2 extracted from the air and C stored by farm forestry during the period 2012/13 to 2016/17 are shown in Table 3.

Table 3. Estimated annual carbon storage and CO_2 absorption by standing plantations.

Sl No.	Year	Plantation area (ha)	Wood production of farm forestry (t)	Carbon stored [t]	Carbon dioxide absorbed [t]
1	2012/13	5,378	239,847	119,924	439,720
2	2013/14	5,650	350,864	175,432	643,251
3	2014/15	7,431	483,433	241,717	886294
4	2015/16	9,260	770,842	385,421	1,413,210
5	2016/17	4,467	593,615	296,808	1,088,294

Conclusions

Leucaena clonal programs have taken 'deep roots' among the farmers in Gujarat and Maharashtra States. This has increased wood production per unit area by 3–4 times compared with seed-planted plantations, thereby increasing net economic returns to the farmers. Clonal *Eucalyptus*, *Casuarina* and *Leucaena* plantations are making immense contributions towards development of wood-based industries, local asset value addition, employment generation, diversification of agriculture, greening of the country and environmental amelioration. Likewise, clonal technology, supported with an improved package of silvocultural management techniques and due safeguards, offers opportunities for substantial improvements in production of plantations and significant enhancement of quality of plantation-grown timber.

Establishment of about 50,000 ha of plantations involving 66,000 farmers in areas surrounding the JK Paper Ltd, CPM unit mill has created a viable and sustainable economic model for farmers, transporters, paper mills and laborers. With these plantations, the CPM unit has developed a sustainable fiber resource to cater for raw material needs into the future. While substantial advances have been made, much more needs to be done to increase productivity and to improve quality of the end products to match international standards.

References

(Note of the editors: All hyperlinks were verified 6 May 2019.)

Brewbaker JL. 1988. Cloning of seedless leucaenas for plantation use. Leucaena Research Reports 9:111-112. bit.ly/2ZJn5Lx

Lal P. 2001. Private sector forestry research: A success story from India. Bois et forêts des tropiques 267(1):33–48. bit.ly/2V5I3ka

Sorensson CT. 1988. Pollinating and emasculating techniques for leucaena species. Leucaena Research Reports 9:127–130. bit.ly/2LrzYa2

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