

## PAST AND PRESENT RESEARCH IN FOUR MULTIPURPOSE TREE SPECIES

M. I. Sheikh\*

### Summary

In this paper research pertaining to four multipurpose tree species viz; *Acacia nilotica*, *Azadirachta indica*, *Dalbergia sissoo* and *Eucalyptus camaldulensis* has been reviewed. Distribution of the species, various nursery and field planting techniques, species trials, rate of growth and yield management of the plantations, water requirement etc. have been discussed.

### The four species

Out of 4 species viz; *Acacia nilotica*, *Dalbergia sissoo*, *Eucalyptus camaldulensis* and *Azadirachta indica*, the first two are native to Pakistan while the others are exotic.

*A. nilotica* is a moderate sized evergreen fast growing tree with large spreading crown. It is indigenous to the province of Sind but it grown throughout the plain of Pakistan. As a matter of fact inspite of being frost tender good specimen in scattered form can also be seen in the foot hills. It is one of the most conspicuous trees in the agricultural lands as well as marginal lands throughout Pakistan. Being a multipurpose tree with many end uses such as fuelwood, timber, tannin, fodder etc. and its tenacity to grow under difficult conditions it has become a favourite on the farmers and graziers of the country. In fact in the province of Sind due to its resistant to salinity and alkalinity it has been growing since ages to reclaim the marginal soils. During the times of fodder scarcity, it is one tree on which farmer can really depend.

Flowers appear twice a year — September — October — January. The seed is available in May and June. Germination is accelerated is keeping it soaked for 24 hours, later sun dried and sown. The farmers also keep it in cow dung for 8—10 days to improve and quicken germination. As a matter of fact the seed is collected from the livestock pens where it is available in abundance. The pods are eaten by the livestock and after due process of digestion the seed comes out in the form of droppings. Even the foresters collect this seed for large scale afforestation.

The common method of raising plantations has been the sowing of treated seeds which germinate after 1—2 weeks. In the province of Sind the seed is spread from the boats in receding water on the banks of river Indus for raising the plantations. The farmers usually sow the seed in lines or in pits known as spot sowing. Now practice of sowing the seed in the polythene tubes and planting has also been started. The usual cultural practices are cleaning, pruning and thinnings in the early stages to remove congestion.

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\*Director General, Pakistan Forest Institute, Peshawar.



A rotation of 20 years is practised with two thinnings at the interval of 7 years each in the riverain forests and at 5 years interval in the irrigated plantations. The yield varies according to the site quality. Final crop is usually harvested at the age of 20 years.

The tree yields useful construction timber which is very hard and durable. Large quantities are used for converting it into charcoal. Bark is used for chemical dyeing of leather. It is extensively used as pit props in the mines. Since the industry is expanding there is great scope for the consumption of the wood of this species.

There is also a sub species known as *A. nilotica* var. *cupressiformis* which grows straight, fairly tall, yielding more clean timber. However if fuelwood is the end use, the other branchy sub species yield much larger quantity of wood.(33)

*Dalbergia sissoo* locally known as shisham or Tahli is a large sized deciduous tree with irregular crown and rarely growing straight. As a matter of fact there is another unidentified variety which grows in North Western Frontier Province specially in Peshawar division which has dropping branches but a clean straight bole and good heart wood making it a prized tree for furniture. The tree is indigenous to sub-Himalayan tract, ascending upto 1200 m. It is the most popular timber species of Pakistan and is cultivated throughout the Indus valley as general utility tree yielding both firewood and furniture timber. It is also the most common tree grown by the farmers in association with agricultural crops as a single tree, in the form of windbreak or even as block plantations.

It sheds its leaves during cold season, new flush of leaves appearing in February-March alongwith fragrant flowers. Seed is available in November-December. When sown in the nursery germination starts within 7-10 days and may continue for 3 weeks. Generally root shoot cuttings are used for raising plantations but direct sowing of the seed may also be done by the farmers. Now, plants are also being raised in polythene tubes.

Being a multipurpose tree, sissoo has innumerable end uses, fuel, charcoal, furniture, building construction, wood carving, household effects, fodder etc. The tree is in fact the backbone of all furniture and timber trade in Pakistan.

The plantations raised from root shoot cutting are worked on 20 years rotation for fuelwood and small timber and 60 years rotation for timber. Thinning interval is usually 5 to 6 years(33)

*Eucalyptus camaldulensis* locally known as "safeda", "gond", or "lachi" is a large tree attaining sizeable girth. The stem is erect and summetrical but often irregular in shape with dropping foliage. The bark is smooth ashy grey or whitish. The tree is capable of growing under a variety of climatic and soil conditions varying from waterlogged to saline soil and marginal lands in the plains and food hills upto an elevation of about 1200 m in the north. The flowers appear in May-June and seed is available in September.

The first introduction of Eucalypts in the subcontinent dates back to 1843 in the form of



single trees, arboreta and roadside plants. In 1900 when it was feared that fungal attack could cause severe losses to *Dalbergia sissoo* plantations, interest in Eucalyptus tree arose. However no substantial area was planted in the last 50 years. The effort to test more species of Eucalypts were revived with the arrival of Mr. Brockway an Australian expert in 1965. Over the years many foresters have visited Australia in the quest to get some suitable species for climatic conditions obtaining in Pakistan. In the process arboreta were set up at Pirawala, Changa Manga, Chichawanti etc. Field trials were also conducted at several places.

In the 1970 plantation programme received a new impetus when it was found that *Euc. camaldulensis* could be raised without irrigation in a rainfall zone of 350 mm with the winter rain. Millions of trees were raised in the nurseries and planted in dry areas, roadside avenues and irrigated plantations. However the farmers are not getting used to it. On the one hand they are committed to the conventional trees such as *Dalbergia sissoo* and *Acacia nilotica* and Poplars and on the other end uses of eucalypts have not been fully identified in view of the refractory nature of the wood.

The usual method of propagation is by the tube plants of 6 to 9 months old at conventional spacing of 3x3 m on a short rotation of 15- 20 years. (33)

*Azadirachta indica*: The species is indigenous to the Central and Southern parts of India. It has been introduced in Pakistan rather casually by the foresters who got interested in the species. The tree is normally seen in lower Punjab and Sind regions. Some good specimen are also available in Lahore Cantt. Very impressive trees can be seen in Hyderabad on Pakistan Highway between Llyods barrage and Rohri. The tree can withstand minor salt concentrations and can grow in calcareous formations.

Flowers appear from March to May and the fruit is available from June to August. The seed has low viability and should be sown immediately after collection. Before sowing the seed should be depulped and soaked in water for a few hours. Germination takes place in about 10 years. ?

Due to its frost tenderness the tree has not been found much favour with the foresters. However, this is a very important species for propagation in the lower Punjab and Sind and large scale planting should be attempted specially on the farm land. (33)

## 2. Nursery techniques

With a view to finding the optimum size of stock, for field planting 3-month, 6-month and 24-month old *E. camaldulensis* seedlings were used. The 6 months old seedlings appeared to be the best for survival and growth. Although 24 months old plant were tallest due to initial advantage of height but these were whipping with few leaves and appeared to be struggling against 3 and 6 month old seedlings which were sturdy with large number of leaves. It was suggested that for all field planting, seedlings should be between 30-36 cm high which the plant normally attains in a period of about 6-8 months. After that there appears to be no justification for keeping the plants in the nursery. (20)



As a result of data collected in a nursery, it was reported that the cost of raising one eucalypts plant was about 15 paises including the cost of the polythene tubes. However, in subsequent studies, due to increase in the price of polythene, cost per plant rose to 100 paises/plant due to increase in the cost of polythene and labour rates. (28, 21).

Nursery techniques for raising *E. camaldulensis* on a large scale have been described by several authors. Instructions regarding seed collection, seed sowing proper soil mixtures, size of polythene containers, transplanting, transportation etc have been given. Field planting techniques outlining instructions for site preparation, planting methods, fertilization, weeding, use of insecticide etc. have also been included. Cost of raising 1 ha of Euc. Plantation has been assessed as US \$ 100 for the year 1982.

Monographs of *E. camaldulensis*, *E. microtheca* and *E. tereticornis* have been prepared emphasising that these are the most important species for large scale planting in Pakistan. In problem areas where *E. camaldulensis* and *E. tereticornis* do not give encouraging results, planting *E. microtheca* has been suggested. (14).

An experiment to see the effect of polythene tube size on the growth of seedlings was initiated in January, 1970 with various tube sizes ranging from 15 to 23 cm in length and 2.5 to 7.5 cm in diameter. Besides other species, *E. camaldulensis* and *Acacia nilotica* were tested. It was indicated that the tube sizes of 15x6.25 (45 perforations) and 15x5 cm (36 perforations) were the most suitable and economical for raising the nurseries. It was also noted that bigger diameter of the tube had a more pronounced effect on the growth of seedlings but the cost of the bags was more and so uneconomical. (25).

In order to see the effect of size of tubes on the development of seedlings, *E. camaldulensis* and *Leucaena leucocephala* were planted in polythene tubes of 2 sizes viz; 17x2.5 cm and 15x4.5 cm. It confirmed the earlier results that plant grown in polythene tubes of bigger diameter grew better. It was further observed that plants of these species should not be kept in the nurseries for more than 8 months otherwise they tend to become weak, suffer from unbalanced root shoot ratio and had lesser chances of survival in the field. (26)

Based on research conducted over a period of time in nursery and field planting techniques of species such as *Acacia nilotica*, *Dalbergia sissoo* and *E. camaldulensis* etc recommendations have been made for the benefit of the field foresters. Time and method of seed collection, storage, sowing, pricking of seedlings, shading, and watering etc. have been outlined. (30)

### 3. Seed source and species trials

Initiation of an active programme of seed tree selection and the establishment of seed orchards has been emphasized with those species of Eucalyptus which have proved successful in Pakistan. It is further been suggested that it would be desirable to introduce species from Australia but these may be restricted to small quantities of seed from selected species and particular provenances of species which show wide variation in natural distribution patterns. (2)



The species most suitable for ecological conditions in Pakistan have been identified as *Eucalyptus tereticornis*, *E. camaldulensis*, *E. microtheca*, *E. citriodora* and *E. melanopholia* (13)

Comparative growth of 10-year old 52 species of Eucalypts raised at Peshawar has been reported. A large variation was observed for the parameters of survival, diameter and height. These differences were found to be highly significant for height and diameter and non significant for survival percent. Out of the species tested, *E. macarthurii* turned out to be the fastest growing attaining a diameter of 22.5 cm followed by *E. botriodes*, *E. kitsoniana*, *E. crebra* etc. with diameters of 19.1, 18.5 and 18.0 cm respectively. The most popular eucalypt now being planted on a large scale i.e. *E. camaldulensis* attained a diameter of 16.5 cm. Field studies preferable provenances trials of the promising species under different ecological conditions were recommended by the authors. (39)

Results of 6-year old provenances trial of 22 provenances of *E. camaldulensis* from Australia were reported in. Quite significant results regarding survival, rate of growth and volume production were indicated. Based on these indications six provenances were finally recommended for large scale planting, the best one being from Newcastle Waters creek and the second best as Katherine, both from Northern Territories. (5)

The results were again compared when the plants were ten years old and were found consistent with the earlier observations. The differences in growth amongst various provenances were statistically significant. The growth rate of fast growing provenances also compared very favourable with the yield of *Dalbergia sissoo*, and *Acacia nilotica* plantations under similar site conditions. (40)

A study was started in 1967 at 5 different locations testing in all 67 species. Planting was done at 3x3 meters. The data collected upto 5 growing seasons were statistically analysed for survival, height, growth and diameter growth. *E. tereticornis* gave the best performance both at Peshawar and Hyderabad. *E. camaldulensis* seemed to have been excluded inadvertently from this study. (10)

Seed source trials of *Acacia nilotica* and *Prosopis cineraria* were started in 1984 in collaboration with FAO/IGPBR project at 2 different sites, namely Dagarkotli and Dhabeji. Useful results were available only from Dagarkotli as the performance of species at Dhabeji could not be accepted as indicative due to a very long drought. Out of 11 seed sources from India and Pakistan, the 1986 data showed that the *Acacia nilotica* Haryana 1081 seed source had gained as average height of 3.26 meters followed by Patoki (Pakistan) source 1168, attaining a height of 2.87 m. However, the best survival was shown by the latter source. As regard *Prosopis cineraria*, the Indian source, 1090 was 1.78 m followed by 1184 from Pakistan with a height of 1.54 meters after about 3 growing seasons. The survival in the latter case was however almost 95% which was better than all the other sources. (1)

#### 4. Field plantings

*Acacia nilotica* and *Prosopis cineraria* were air seeded in the riverain forest of Sind. The



preliminary ground assessment of the area which received the first aerial seeding on 11-9-1974 was done on October 14, 1974. 48 seedlings per 3.35 sq. meters could be counted. A total of 2030 hectares was sown, at the cost of US \$ 200 per hectare. The operation was considered to be successful. (10)

Plastic aprons of different colours and thickness were tested to find out their effect on survival and growth on *Dalbergia sissoo* and *E. camaldulensis* at Peshawar and Jallo. The results indicated that survival of plants was significant; the rate of growth was better when aprons were used; the material and colour of apron had significant effect on height. Irrigation was given only at the time of planting and no further watering was done. All treatments gave better results as compared to the control i.e. no apron. It was concluded that plastic aprons were useful as a mulch and showed their effect on height growth. (37)

A study was started in 1975 to compare the survival and growth of 3 species viz; *E. camaldulensis*, *Ceratonia siliqua* and *Zizyphus mauritiana* with major treatments such as deep and shallow ploughing, minor treatment shallow planting with mulch; and shallow planting without mulch, deep planting with mulch, deep planting without mulch in 3 replications. The study was first assessed in 1977 and it was found that survival of the Eucalyptus was the best irrespective of the major or minor treatments. Observations were again recorded in February 1982. *E. camaldulensis* had gained average height of 12 meters and diameter of 13.6 cm as compared to 4.15 m ht and 3.94 cm diameter for *Zizyphus mauritiana* and 2.61 m ht. and 2.39 cm dia for *Ceratonia siliqua* indicating highly significant growth for *E. camaldulensis*. No treatment had any effect on any of the species. (35)

Effect of root length on survival and growth of 9-month old seedlings of *E. camaldulensis* raised in polythene tubes was studied. Special polythene tubes were designed to accommodate the different length of roots viz; 18, 30, 45, 60 cm. The maximum survival was obtained with the root length of 30 cm. The height obtained after a period of 7 months which were more than 1 m in all the cases were not significantly different. (19)

In a study near Peshawar, (average annual rainfall 350 mm) to compare the growth of *E. camaldulensis* with *Tecoma undulata* and *Acacia cyanophylla*, *E. camaldulensis* averaged a height of 10.26 m after 4 growing season as compared to 3.3 m by *A. cyanophylla* and 1.82 by *T. undulata*. Similarly when *E. camaldulensis* was compared with *A. modesta* and *Gleditschia triacanthos*, *E. camaldulensis* averaged a height of 4.18 as compared to 2.18 for *Acacia modesta* and one meter by *G. triacanthos* after 3 years. (22)

*E. camaldulensis* was planted in Chichawanti irrigated plantation at 3 different spacing viz; 1.5x1.5, 2.25x2.25 and 3x3 under flood and trench method of irrigation. While the method of irrigation did not have any effect on the crop yield, the spacings were highly significant. The closest spacings produced 95 m<sup>3</sup> of wood per hectare, and the wider spacings 61 m<sup>3</sup> per hectare and 38 m<sup>3</sup> per ha respectively after a period of four and half years. The same trend was observed in two other irrigated plantations namely Pirawala and Bahawalpur. Also wider spacings were highly infested with weed as compared to the closer spacings. The study gave a very important indication that for maximum volume production at a short rotation *E. camaldulensis* should be planted at 1.5x1.5 meter spacings. (22)



A small scale experiment covering an area of 1.5 acres was conducted to find out the rate of growth of *Eucalyptus camaldulensis* under 4 different spacings under trench irrigation 1x2, 2x3, 3x3 meters and flood irrigation, 1x1, 1.25x1.25 m. The study was started in 1968 and assessed in 1972. It was found that different in height and diameter under flood and trench system of irrigation was not significant. The difference in spacings was also not significant but the treatments were highly significant in flood irrigation plots indicating that closer spacings higher the yield/unit area. (23)

Effect of method of irrigation and fertilization were tested on *Eucalyptus tereticornis* in 1968. The treatments included trench irrigation, with chemical fertilization; flood irrigation; and green manuring with flood irrigation. The treatments were not significant. Although dbh 9 cm under flood irrigation and green manuring with flood irrigation, 9 cm, was better than trench irrigation and chemical fertilization with trench irrigation, 8.25 cm. (24)

In a study conducted in Setharja to evaluate different species for planting in saline soils with PH varying from 8.5-9.5. *E. camaldulensis* gave 90% survival and 2.6' height in one year. Similarly *Acacia nilotica* gave 100% survival and the best height of 5.4' when compared with 9 other species. Similar performance was given by *E. camaldulensis* in the waterlogged area of Shorkot plantation. In Azakhel *E. camaldulensis* again performed very well giving 80% survival and a height of two meters in one growing season. The above result clearly indicate the suitability of *E. camaldulensis* over other species for afforestation in saline areas and waterlogged areas. (29)

### Planting and management

The irrigated plantations in the Indus plain cover an area of 0.2 million ha. These man-made forests been formed out of the wastelands which came under extensive irrigation system. The species such as *Dalbergia sissoo*, *Morus alba*, *Salmalia malabarica*, Eucalypts, *Acacia nilotica* and *Hybrid poplars* have been raised. These plantations have been developed with much too different techniques as compared to the usual forestry practices. The foresters here are not only concerned with regeneration, silvicultural operations management and exploitation but also with irrigation, lay out, proper flow, fair distribution of water, etc. Various steps involved are survey of the area, plotting of the survey plan, demarcation on the ground, levelling and preparation of contour and command maps. The area is divided into compartments varying in size from 20-24 ha according to the site conditions. After preparation of the area, planting is done either in trenches or in level plots at a spacing of 2x3 m with 6-9 month old root shoot cuttings in case of *Dalbergia sissoo*. Eucalyptus planting stock is raised in polythene tubes while patch or line sowing of *A. nilotica* is done. Now tubelings of *A. nilotica* are also used. The tending operation include, weeding, cleaning, pruning and thinning etc. In case of *D. sissoo* thinning is done at the age of 5, 10 and 15 years and final felling is done at the age of 20-22 years leaving 25 trees per ha which become timber trees on a rotation of 40-60 years. At the age of 22 years the average diameter is 30 cm. The total yield obtained as a result of thinnings is about 100 m<sup>3</sup>/ha and at the time of final felling another 90-100 m<sup>3</sup> of wood is available.



*Acacia nilotica* and *E. camaldulensis* are worked on a rotation of 15-20-30 years and no trees are left in the field to become timber trees.(28)

To test the performance of five species under saline conditions, (PH 8.5) a study was laid out at Military Dairy Farm Risalpur during February, 1986. Five species viz; *E. camaldulensis*, *E. microtheca*, *Albizia procera*, *Casuarina cunninghamiana*, *Leucaena leucocephala* were planted in four replications. 144 plants of each species were planted in each plot at 2x2 m spacing.

The survival of plants was recorded in July, 1987, *E. camaldulensis* gave 56% survival as compared to 70% of *Casuarina cunninghamiana*, and 66% of *Leucaena leucocephala*. On the lower side *E. microtheca* and *A. procera* showed 34 and 24% survival. However *E. camaldulensis* grew the fastest of all 1.5 m average height.(1)

To find out the comparative rate of growth of *Populus deltoides* 1-63/51, *Eucalyptus citriodora*, *Dalbergia sissoo* and *Salmalia malabarica*, a study was planted in Peshawar in February, 1978, 120 plants of each species were planted in 16 sub-plots at a spacing of 4.3x4.3 m. In each sub-plots 24 plants were planted, 480 plants in all. Planting was done in a randomised complete block design, replicated 4 times.

While one-year old entire plants of *Populus deltoides* and tubed plants of *Eucalyptus citriodora* were planted, root shoot cuttings of *Dalbergia sissoo* and *Salmalia malabarica* were used in the study.

A variety of agricultural crops, one after the other were planted in between the lines. These include *Sesamum indicum*, maize and wheat.

Data on height and diameter were recorded in February, 1983. The best dia and ht. 21.1 cm and 16.61 m was shown by *P. deltoides* CVI 63/51. The other three species viz; *Salmalia malabarica*, *Dalbergia sissoo*, and *E. citriodora* reached 19.8, 14.8 and 14.6 cm dia and 9.2, 10.4 and 13.6 m height.(1)

*Dalbergia sissoo* was planted at three spacings in 1978 viz; (A) 4x4 (B) 3x3 (C) 2x2 m. Data on ht. and dia growth in 1987 were 18.5 cm dia. 14.3 m ht. 15.2 cm dia and 13.7 m ht. and 14.0 cm dia and 13.2 m ht. for A,B,C, respectively. The trees planted on wider spacing showed better dia growth. However the trees in the closest spacing, had more length of clear bole comparatively lesser number of branches which were also thinner in size.(1)

#### Block plantations by farmers.

History of development of *Acacia nilotica* block plantations known as Hurries in the province of Sind was studied. Methods of planting, treatment of the crop, expenditure and revenue and researchable areas were discussed. The important benefits which accrue to the farmer are: improvement of the soil, leading to better agricultural crops subsequently; a net financial return of about 100 US dollar per ha per annum from the sale of wood with a cost benefit ratio of 1:1.72. There is lot of scope for further development of hurries in view of the



extensive use of wood as pit props for the ever expanding mining industry. There is also a higher trend in the market for prices of timber and fuelwood. For instance timber sells at a rate as high as 200 US \$/m<sup>3</sup> and fuelwood for US \$ 5.5/quintal.

The researchable areas indicated by the author are: proper management of the crop; tree/crop interface; use as a minor forest produce in production of tannin, shellac, gum and honey; extension of hurries to other parts of the country; introduction of some new species as alternate to *A. nilotica* and also the socio-economic impact of the system. More positive attitude of the forest department towards Hurries development emphasized.(31)

While surveying the Hurry plantations in Sind it was reported that 1,3 & 5 year old plantations of *Acacia nilotica* were growing at a spacing of 0.9x0.9, 1.1x1.1 and 1.2x1.2 m respectively. Generally speaking the Hurries showed good dia growth upto 5 years with an average annual increment of 2.3 cm dia and subsequently declined due to crop congestion. The author is of the opinion that the rate of growth could be enhanced even upto that age if proper silvicultural operations like pruning, cleaning, thinnings could be introduced.

As regards production of biomass it was indicated that it levelled off at 4.9 kg per tree at 3 years age. This is however related to crown width spacing. The largest amount of tree biomass was 1-7.5 cm dia class for ages 3,5, & 7.(17)

### Tree crop interface

As far back as 1960 planting of shelterbelt of *Dalbergia sissoo* in different parts of Thal desert was done along roads, canals and railway lines to check the drift of sand and reduce the severity of the sand storms. This was considered highly imperative for development of agricultural land establishment of new habitation and towns in the wilderness.(41)

Importance of raising trees on farmlands has often been emphasized indicating that the farmer has to be convinced that trees would bring no harm to his agricultural crops and that he would be much better off financially by practising agro-forestry. It was suggested that to achieve the objectives, government machinery would have to be geared to a high a pitch through proper motivation and help to the farmers in the form of subsidy, loans, rewards, exemption from taxes etc. The usual points put forth by the farmers against tree planting include small size of the holdings; competition by trees for water, nutrients and sunlight, trees as career of diseases and the role of the birds which pick up the grain.(18)

Studies were started in 1978 to find out the effect of tree shade on the yield of wheat. It was found that the scattered trees of *Acacia nilotica* and *Dalbergia sissoo* growing in farmer's fields did have a deleterious effect on wheat yield, the maximum loss being within 2 m radius of the tree. It was also seen that the yield was poorer from the portion of the crop falling on the northern side of the tree. The grains of the crop collected from close proximity of the trees were shrivelled indicating that the crop had not matured fully as compared to the crop away from the shade.(34)



Effect of different tree species on the yield of wheat has been reported. The yield of grains under *E. camaldulensis*, *Salmaal malabarica*, *Dalbergia sissoo* and Poplar was 32, 34, 35 and 24 quintals per hectare respectively while the yield of straw was 33, 36, 39 and 27 quintals per hectare. None of the above differences were significant except in the case of poplar. The trees were spaced at 4.3 x 4.3 m and were only 2 years old when the study was conducted.(12)

*E. camaldulensis* was planted in January, 1980 in the form of shelterbelts 3 rows in each belt, plants being 2 metres row to row and 1 meter plant to plant in each row, belts being 180 m apart. The trees attained an average height of 15 metres and a diameter of 15–20 cm by the middle of 1986. In the sheltered area it was found that cotton and maize were adversely affected within about 10 metres distance of the belt because of shade and root competition for water and nutrient on either side of the belt, the effect being comparatively milder on the plots falling on western and south western side of the belt. However, beyond the 10 meter distance the belt had a positive effect on the yield. In October, 1985 one complete row from each belt was removed on the northern side which yielded about 1200 poles or about 170 m<sup>3</sup> of wood to the farmers.(36)

In Thal desert shelterbelt of *Dalbergia sissoo* were planted at right angles to the prevailing wind direction using 6 months old root shoot cuttings in 3 belts spaced 122 metres apart. Each belt is composed of 3 rows with 2 metres row and 3 metres plant to plant distance, duly staggered. The belts are 370 metres, 475 metres and 570 metres in length. About 90% trees survived and gained a height of 4 metres in 3 years. Wheat crop was sown for a couple of years along the belt. Yield of wheat on different distances from the belt were measured. These indicated about 1000 kg per ha. at a distance of 0–3 metres from the belt going upto maximum of 2000 at a distance between 35–40 metres and then again coming down to 1450 kg per hectare between 55–60 metres. No doubt the yields were low near the belt but there was an overall increase of 1 quintal per ha. Apart from the effect of trees the practice of removing soil after sowing to strengthen the water courses and vigorous growth of weeds along the water courses due to availability of moisture reduced and hampered germination. A very visible mark of the belt was minimum lodging in the protected area resulting in an increase as indicated above. There was reduction in the average yield as the tree grew bigger.

In the same desertic region effect of *Dalbergia sissoo* trees on yield of wheat was assessed with similar results. The average yield was never less than the control.(36)

Planting of *Acacia nilotica* at a spacing of 2x7 metres and growing of agricultural crops such as cotton wheat, sesamum, sorghum etc. in between the rows of trees has been practised in several parts of Sind on the land leased by the forest department for a period of three years. It was reported that after three years where as upto 36 m of wood was available from one hectare from the area where tree rows were intercropped, about 30 m<sup>3</sup> of wood/ha was obtained from the land where no cropping was done. It indicated that trees had been benefitted by additional irrigation, land cultivation and fertilization. The tree rows however, did not depress the crop.(11)

The effect of tree windbreaks/shelterbelts has been studies in Thal desert (Pakistan) on



the yield of wheat crop in 1984 grown under irrigated conditions. Wheat was sampled in one meter sq plots along transect lines on the leeward side. The results obtained indicate a net gain in grain yield. There was a loss of grain near the tree row which could be minimized by improved cultural practices and control of weeds. However, the economic gain from the sale of wood obtained from windbreaks more than compensated the loss.(38)

### Water requirement for optimum growth

Surface irrigation with drip system of irrigation was compared to assess the survival and rate of growth of *E. camaldulensis*. It was found that over a period of 7 months *E. camaldulensis* gave a good survival and rate of growth under the drip system of irrigation. Average heights under 3 systems viz drip, trench and flood were 102, 105 and 123 cm after 7 months respectively. Although the net growth recorded for the plants under drip system is the lowest yet it compared very favourably with other systems taking into account the quantity of water supplied. The trench and flood system of irrigation received 5 and 7 times the quantity of water respectively.(32)

In order to find the optimum quantity required by *Dalbergia sissoo*, use of five deltas 0.46, 0.91, 1.37, 1.83, 2.3 m, three frequencies fortnightly, 3-weekly, monthly, and two methods, trench, and flood system has been reported. It was found that amongst the 3 variables put to test quantity of water was the most important factor. The study further indicated that increase in growth was more pronounced when delta was increased from 0.91 to 1.37 m; that method of irrigation had no effect; that fortnightly irrigation gave more volume per unit area. Another finding was that if irrigation was properly regulated, it was possible to get at least 75 m<sup>3</sup> of wood per ha at the time of second thinning against routine yield of 30 m<sup>3</sup>/ha. (18a).

A water requirements study was started in Chichawatni irrigated plantations in 1977 to ascertain the effect of 3 deltas of water viz; 0.9, (A), 1.4 (B), 1.8 (c) metres on 4 species namely *Eucalyptus camaldulensis*, *Salmaal malabarica*, *Morus alba* and four exotic clones of poplars. After a period of about 8 years it was found that there was almost linear relationship between the dose of water applied and the volume produced. In 1987, *E. camaldulensis* had gained an average height of 23.1 m and dia of 23.6 cm under delta A, 22.9 m height and 24.3 cm diameter under delta B and 24.6 m. height 25.5 cm diameter under delta C.(1).

Another study on water requirement was started in Peshawar in 1986. *E. camaldulensis*, *Dalbergia sissoo* and *Acacia nilotica* were there besides other 4 species to find out the effect of irrigation of data indicated the best height growth by *E. camaldulensis* under almost all frequencies of irrigation as compared to the rest of the species. There were no significant differences between the average height attained by *Acacia nilotica* under different treatment of irrigation. However, the best growth was indicated by 10 days, and 20 days intervals of irrigation. Similarly in the case of *Dalbergia sissoo* almost equal growth was obtained (3.52 meters) under 10 days and 20 days interval as compared to 30 and 40 days interval in which case it was only 2.1 metres. The average quantity of water delivered in all the cases was 0.9 m delta.(1).

Excepting *Azadirachta indica*, volume tables of other species have been prepared. Simi-



larly provisional/interim yield tables of the above three species are also available. A brief resume of work done is given below:

- (i) *A. nilotica*: Volume tables for linear plantation of Sind (4), canal plantations of the Punjab (16) and riverain forests of Sind (15) were prepared. Yield tables of the species (3) with a rotation of 20 years MAI (mean annual increment) for three quality classes are as under:

Quality class	I	II	III
MAI (including thinning) m3/hectare	10.3	8.4	6.4

- (ii) *Dalbergia sissoo*: Plantations of this species are worked on a rotation of 20 years for fuelwood production. Normally three thinnings are carried after 5, 10 and 15 years of the age of the crop. Volume tables for the species for all the irrigated plantations of the Punjab (8) are available. The tables show the contents against both dbh and height as well as against dbh only i.e. standard and local volume tables. Volume tables for linear plantations were prepared in 1973 (6). Provisional yield tables for the irrigated plantations were prepared in 1978 (7). MAI at the age of 20 years for three site quality is given below:

Site quality	I	II	III
MAI (including thinnings) m3/hectare	11.2	8.4	5.9

- (iii) *Eucalyptus camaldulensis*: The rotation age for the species is 10 years. The volume tables were prepared for irrigated plantations of the Punjab in 1979 which are of two types viz. standard and local. The provisional yield tables prepared in 1983 (8) are based on three spacings viz; 1.5x1.5 m, 3x1.8 m and 3x3 m. The MAI (mean annual increment) for different spacings are given below:

Age	Spacing		
	1.5x1.5 m (MAI (m3/ha))	3x1.8 m	3x3 m
5	31.9	26.0	18.7
10	—	—	22.2

In the case of *Azadirachta indica* MAI has been estimated at 5–8 m3/ha.

#### Future prospects and researchable areas

No doubt *Dalbergia sissoo* and *Acacia nilotica* have been very extensively planted, extensively planted, *E. camaldulensis* and *Azadirachta Indica* need more attention for population these multipurpose species with the foresters as well as farmers. Some very important researchable areas are indicated to give the species a more positive thrust. These include seed source trials; water requirements; comparison with other species; establishment of seed orchards; and finding new end uses etc. Research and demonstration centres are required to be set up right in the desert areas with proper outreach support.



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