Life sciences Leaflets 8: 69-80,2012 FREE DOWNLOAD ISSN 2277-4297(Print)0976–1098(Online)

Published on: 1st Aug 2012

REVIEW - AN OVERVIEW OF EXOTIC FORESTRY IN INDIA

AARIF ALI GATTOO

DEPARTMENT OF FORESTRY, SHER E KASHMIR UNIVERSITY OF AGRICULTURAL SCIENCES AND TECHNOLOGY OF KASHMIR, SHALIMAR SRINAGAR- 191121 (J&K)

aarifali123@gmail.com

ABSTRACT:

Forests are the Earth's largest, most productive ecosystems, playing one of the biggest roles in the development of human societies. With forest cover shrinking, the current demand for forest products may exceed the limits of sustainable consumption. To meet the growing demand, exotic tree species are often planted. The exotics are generally fast growing, more productive per unit area as compared to indigenous species. In order to introduce the exotic species, factors like edaphic, climatic, forest types etc. should be taken into consideration. There are a number of potential fast growing exotic tree genera like *Populus, Eucalyptus, Prosopis, Sesbania, Casuarina, Acacia*, etc., which have the potential to take intensive pressure of the natural forests. There is a huge scope for exotic trees in agroforestry, energy plantations, industrial plantation, wasteland plantation and strip plantation. Various researchers have reported success stories of exotic plants in increasing the net returns from agriculture fields, reclaiming saline and alkali soils, afforestation in opencast coal mines etc. Apart from these advantages, there are various negative impacts of exotic trees viz. Allelopathy, liable to attack by pests and disease, use of excess water, effect on soil and invasive nature.

KEY WORD: *Exotics, Fast growing trees, Allelopathy.*

INTRODUCTION:

The forests are indispensable part of human life without which the very survival of life on globe is impossible. Forest resources should be sustainably managed to meet the social, economic, cultural and spiritual human needs of present and future generations. Ever increasing requirement for timber, fodder, fuel wood and fiber have threatened the sustainability of forest production systems. The rapid increase in greenhouse gases in the atmosphere, land degradation, increasing floods and droughts, marching deserts and deteriorating conditions of fragile ecosystems, deforestation, loss of biodiversity and environmental pollution have become subjects of serious global concern. Despite the framing of National Forest policies of 1952 and 1988 in India and enacting new acts in post-independence period, it has not been possible to conserve and enhance the forest cover. According to the National Forest Policy of 1988, 33.3 per cent of the total geographical area of the country should be under forests. But the area under forests is 69.09 m ha i.e. 21.02 percent of the geographical area (FSI, 2009). Our forests have very low growing stock i.e., 47 m^3/ ha as compared to world average of 114 m^3 / ha and mean annual increment of forests is also very low i.e., 0.7 m^3/ha/yr compared to world average of 2.1 cum/ha/yr (Chauhan *et al*, 2008). Eventually there is great need to increase the area under tree cover and to improve the productivity. The policy was advocated to move towards a more dynamic programme of converting the natural less productive forests into plantations of fast growing exotic species. Exotic species are utilized to supplement or replace the local indigenous species that cannot produce the desired quantity and quality of products when the local species have been destroyed or when the suitable trees are not present. Most requirements of wood based industries were met from government owned forests. The state governments had entered into long-term agreements with the industries to supply the raw material. The new forest policy of 1988 completely reversed this agreement. Now the industries have to meet their requirements from trees grown on non-forestlands. Government forests are to be managed for ecological security and meet the requirements of the local communities. Recently Supreme Court imposed the complete ban on the green felling from the state forests. With this change in policy, exotics which have established as good plantation species viz., *Eucalyptus, Poplar, Acacia, Leucaena, Prosopis, Cryptomeria, Casuarina, Jatropha*, etc. find more potential. The practice of introducing trees into new homes is as old as civilization itself. The Romans are believed to have introduced into Great Britain certain continental trees, including the lime and Spanish chestnut. A great impetus to the cultivation of exotics was given after the discovery and exploration of North America with its wealth of conifers. Of these eastern species were naturally the first to be tried in Great Britain, *Pinus strobus* having being introduced in the early part of 18th century, while Douglas fir of the west did not make its appearance for another hundred years. In South Africa, the oak and the ash were successfully introduced from Holland before the middle of 17th century, since then large numbers of species have been tried. In Australia, New Zealand, Kenya, India and other countries the cultivation of exotics have been actively taken up and extensively carried out (Zobel and Talbert, 1984). The five most common exotics in the world are *Eucalyptus grandis, Eucalyptus robusta, Tectona grandis, Pinus caribaea and Pinus patula* (Luna, 2006).

Necessary precautions taken for introduction of Exotic trees:

1. Make a decision about the objective of planting and objects desired. Then, determine the category of trees (e.g. Pines or Hardwoods)
2. Obtain the information possible, from the literature and plantations or from tests that may be available. This informational phase should include visiting areas with similar environments and species to those that will be used for establishing plantations.

3. Survey the area for any plantation of desired species that may be available. Immediately develop Land races from these plantations for use as an immediate source of seed, unless the provenances of the plantation are obviously very unsuitable.
4. Make a systematic investigation through planting trials of potential species and provenances to determine their growth and variation patterns. Obtain seed from the best trees from these plantings to use as a good land race. Obtain improved stock through additional testing and seed orchard establishment to develop a permanent supply for operational planting. Choice of species or provenances to test must be made by using common sense, experience, and through matching environmental extremes and sequences.
5. Operationally, use seed from the initial land race or best potential provenances while better material is being developed through a tree improvement programme.

Success of exotic trees

The exotic species are used for rapid forestation, short rotation, and other economic purposes to bring the forests back at a faster rate than native species. Exotic tree species affect the economy at micro and macro levels. In many situations, the decisions to plant exotic species have been based on the economy as the first and foremost concern. Chopra (2008) reported that one hectare of degraded land, planted with exotic species *viz*. *Casuarina, Acacia, Eucalyptus* and *leucaena* has production equivalent to 20 hectares of indigenous plantation. Thus the plantation of such species has proved to be boon. Similarly, Sharma *et al* (2009) studied the growth and suitability of three exotic Pine species *i.e. Pinus patula, pinus greggi* and *Pinus elliottii* in Uttrakhand Himalayas and made its comparison with the principal indigenous species *Pinus roxburghii.* The study revealed that exotic pines had significantly higher growth, volume production, increment and relative growth rate compared to *P. roxburghii.*

Social forestry programs have been implemented to improve forests conditions and meet growing demand for local forest products. Social forestry has played a vital role in the expansion of forest cover and improving the quality of life for many rural communities. Results from several studies led to support the introduction of exotic species in Social forestry programme and agriculture lands. Davidson (1985) recommends the introduction of Eucalyptus in Social Forestry programme, because of the tree's almost unique ability to adapt to wide range of sites and at the same time grow more rapidly than other genera under widely varying environmental conditions. Harsh (2002) studied the economic return from the agri-silvicultural model of Bajra and *Acacia tortilis*. The comparative economic analysis revealed that growing bajra only on the dunes can give the gross return of Rs. 1,600/ha/year and growing *Acacia tortilis* for the fixation purpose can give the gross return of Rs. 1,493/ha/year at a rotation of 15 years. But by using the improved agroforestry model i.e. growing of bajra with *Acacia tortilis* (160 trees / ha / year), the gross returns can be Rs. 2,002/ha/year. In addition to improved model, gum exudation technique superimposed and then the gross return from agroforestry model can be Rs. 2,728 / ha / year. Kaikini (1967) suggested that *Eucalyptus* is highly suitable for Social forestry. To meet the raw material demand of pulpwood industries which began to increase very fast during 1960's, fast growing species were needed which could adapt themselves to the different agro-climatic zones existing in India. After several other trees were tried the genus *Eucalyptus* was found to be ideal. Pryor (1976) and Tiwari (1983) have expressed similar opinion. Rai *et al* (2008) reported that in a study of hedge row plantations of *Leucaena leucocephala* with maize, blackgram and Clusterbean at Chandigarh, there was an average reduction of 38, 34 and 29 percent in the yield of maize, black gram and Cluster bean respectively, over pure crop. This reduction in yield of crops was compensated by relatively higher fodder and fuel production of Leucaena. Maximum return was obtained when Leucaena was intercropped with cluster bean and Black gram as compared to growing of pure Leucaena and crop. Shiva and Bartwal (2008) studied the yield and income from *Eucalyptus* and *Leucaena leucocephala* grown on irrigated field boundaries. They reported the additional income of Rs. 20,546 and Rs. 4,135 from *Eucalyptus* and *Leucaena* trees planted on agriculture crop boundaries, in addition to income from agriculture crops. Goel and Behl (1992) reported that *Prosopis* wood has excellent burning qualities, burning evenly and hot. It has a good heat of combustion resulting from the high content of carbon and lignin. Furthermore, the estimated calorific value of *Prosopis* is 4,216 kcal/kg and another advantage of *Prosopis* firewood is that it burns well even when green. *Prosopis* also produce high quality charcoal. About 3-6 kg of wood is required to produce 1 kg of charcoal.

Several authors have reported that exotic plantations impart a favourable role in the biological reclamation of soils. Dutta and Aggarwal (2003) assessed the Growth performance, biomass accumulation, and net primary productivity (NPP) of five exotic plant species planted to stabilize and improve the coal mine spoils in India. The selected exotic species were very successful under afforestation programs on wastelands. On the basis of biomass and primary productivity, *E. hybrid* and *Acacia auriculiformis* were found suitable for plantation on coal mine spoil land. Singh (1996) conducted a study to investigate long-term dynamics in *Prosopis juliflora* stands planted to rehabilitate sodic soils in Haryana. He reported that after eight years, the soil ph had gone down and Organic carbon was increased from their initial value (table 1). Singh and Singh (1993) carried out a study on *Prosopis juliflora* and reported that it helps in reclaiming salt affected soils more effectively than trees like *Acacia, Eucalyptus, Terminalia* and *Albizzia* of the same age and stocking rate. Furthermore, they also reported the higher biomass accumulation in *Prosopis* (260 t/ha) in comparison to *Acacia* (215 t/ha), *Casuarina* (188 t/ha) and *Eucalyptus* (148 t/ha). Kohli *et al* (1998) reported that *Eucalyptus* allelochemicals have a great potential to suppress weeds and thus serve as ideal herbicides, which are environmentally safe and biodegradable. Its oils have been reported to suppress and inhibit noxious weed *Parthenium hysterophorous*. Even aqueous extracts of its bark and leaves have been studied to possess the ability to inhibit the weeds.

Table 1: Reclaiming effects of *Prosopis juliflora* plantations on village community lands

Village	Depth (In cms)	Soil properties			
		Ph		Organic Carbon	
		Initial	After 8 years	Initial	After 8 years
Shera	0-15	10.0	8.8	0.13	0.48
	15-30	10.1	9.6	0.06	0.21
Sutana	0-15	10.2	8.5	0.20	0.40
	15-30	10.6	9.4	0.07	0.09
Nain	0-15	9.7	8.6	0.08	0.45
	15-30	10.2	9.2	0.10	0.12
Balsi	0-15	10.0	8.8	0.22	0.65
	15-30	10.5	10.1	0.08	0.12

Constraints in introduction of exotic trees

Despite the apparent benefits discussed above, there have been some adverse public reactions against planting of exotics. The criticisms are based on following problems with exotics.

1. Immediate failure of plantations

When exotics are introduced severe damage or death of plantation is obvious due to changed environment conditions. Sometimes there is complete failure of plantations.

2. Delayed failure

Initially there is good survival and growth, but the trees do not develop properly. This occurs when high elevation or high-latitude trees are planted at lower elevations or vice versa.

a) There is good survival and growth rate but the wood is not suitable. The quality of wood get affected especially when temperate species are planted in tropical or sub-tropical climates.

b) The exotic trees initially have good survival and growth rate but are later attacked by pests or damaged by adverse environmental conditions. This loss is extensive and long term and is frequent cause of failure of exotic plantations.

3. Continued substandard performance

This problem causes the greatest losses when species or provenances are planted off site resulting in low production and poor quality.

4. Absence of suitable mycorrhizae

This has been a major problem with many exotic plantings, especially in the tropics. The soil in the exotic environment is often marginal for survival and growth of the proper mycorrhizal fungi.

5. Soil limitations

Edaphic or soil problems can be a major source of difficulty when growing exotics. This may result from obscure interactions among pH, nutrients and soil types. All soil properties also interact with the climate, and often it is a given weather pattern in combination with soil deficiencies that causes problem in growing exotics.

a) Soil acidity

Although all soil factors are of importance but one that often is especially restricting is the acidity of the soil or soil pH. Some species are very restricted in their tolerance to pH of the soil and are quite incapable of growing on soils with wrong pH. Planting on soils with an unsuitable pH has resulted in the failure of large plantation programmes.

b) Soil nutrients

The deficiencies or excesses of certain nutrients play important role in the growth of exotics. Exotics use heavy nutrients and grow with great vigour in the absence of pests. The very fast growth is likely to deplete soil nutrients more rapidly than in the case of slower growing forests. Therefore a basic rule in growing exotics is to obtain soil samples to determine excesses or deficiencies in soil.

c) Other soil properties

Numerous soil properties other than nutrients are limiting to the growth of exotic trees. These soil properties include differences in soil structure and soil texture that greatly affect tree growth. Some species have wide adaptability and can grow equally well on sandy and clay soils, or on well drained or compacted soils. A common adverse result is that the exotic will grow well for a few years, and then growth will slow with dieback sometimes followed by death if planted on the wrong soil.

d) Need of Mycorrhizae

Since mycorrhizae are necessary for most species as an aid in the uptake of nutrients from the soil, they are absolutely essential for normal tree growth. Without them growth is slow, leaves become yellow and stunted, and frequently the plant is so stressed that it dies following weather extremes.

e) Weather limitations

One of the most frequent causes of failure of exotics is adverse weather. Damage is usually related to heat or moisture stress, which weakens the plant, making it susceptible to other pests. Extremes of weather result in loss in growth and quality, or even in death of the exotic plantations.

f) Pest and exotics

A most common statement related to exotics is that they are more susceptible to pests than are indigenous species. Usually, the exotic is not initially well adapted to its new environment, so the trees in new area are growing under stress, making them more susceptible to pest attack. The pest attack will frequently result from the severe stresses that often occur where exotics are grown. The poor physiological conditions of the trees under these stresses enhance the spread and damage by pests. Another main reason of susceptibility of exotics is their monoculture. Mostly exotics are planted in monoculture and they are more liable to insect and disease epidemics. Many large exotic programmes have failed because pest attacks were not anticipated. Some commonly reported pests and pathogens of exotic species have been shown in table 2.

Table 2: Commonly reported pest and pathogen of Exotics

Pests and Pathogen	Exotic Host
Trichosproium vesiculosum	*Casuarina equisetifolia*
Corticum solmonicolor	*Eucalyptus*
Pleurotus ostreatus	*Acacia*
Fomus	*Hevea*
Ganoderma	*Casuarina*, *Eucalyptus* spp., *Populus* spp.
Armillaria mellea	*Populus spp*

Unusual problems with growing exotic trees

1) Poisoning of soil by Trees- Allelopathy

Several authors have reported adverse reaction against the planting of exotics based on a range of technical, ecological and socio-economic arguments. One of the ecological arguments is that, exotics threaten biodiversity and habitat quality by a phenomenon called 'Allelopathy'. Allelopathy is a new field of study examining the inhibitory biochemical interactions between plants. The provision of allelochemicals from certain species' leaves or litter may have potential to inhibit the germination or growth of other plant species (FAO 1985). Allelopathic effects of various species have been reported by several authors in table 3. Allelopathic effects from certain exotic tree species show competitive behaviour different from that of the native communities in which they invade, and are thought to be linked in part to the invasiveness that sometimes displaces native 8 species (Nasir *et al.* 2005). As a new field of study, direct allelopathic relationships are often difficult to determine through abiotic and biotic factors, and significance of allelopathy in plant research remains controversial. The long-term ecological consequences of allelopathic tree species can only be hypothesized; however, the chemical interference from allelochemicals of many exotic plant species is certain (Jagger & Pender 2003).

Table 3: List of exotic tree species and the parts affected by their allelochemicals

Species	Parts affecting	Literature Source
Acacia spp	Root, leaf & stem	Srinivasan *et al.,* 1990
Ailanthus altissima	Root, leaf & stem	Heisey, 1997
Eucalyptus camaldulensis	volatile, litter	Del moral & Muller, 1970
Eucalyptus globulus	Root, leaf & stem	Del moral & Muller, 1969
Eucalyptus spp.	Root, leaf & stem	Chellamuthu *et al.*, 1997
Leucaena spp.	Root, leaf & stem	Srinivasan *et al.,* 1990
Populus deltoides	Root, leaf & stem	Kil, 1992
Prosopis juliflora	Root, leaf & stem	Chellamuthu *et al.,* 1997
Slight Effect		
Casuarina spp	Root, leaf & stem	Jadhav & Gaynar, 1995

Moral and Muller (1970) reported that a number of allelochemicals such as Phenolic acids and Salicin (A phenolic glucoside) was detected in the aqueous leaf extracts and soil collected under the canopy of mature trees of *Populus deltoides.* Rizvi *et al* (1999) reported that a number of exotic species like *Acacia* *spp., Eucalyptus spp., Leucaena leucocephala* and *Populus deltoids* etc. are known to possess allelopathic potential. Shiva and Bandyopadhyay (1987) studied the toxic effects of *Eucalyptus* and reported that due to allelopathic properties, which serve to reduce not only other plant life, including crops, by restricting germination of other species, but is also detrimental to soil micro and macrofauna. Singh (1996) reported that the species grown in India especially *E. tereticornis, E. citriodora* and *E. globulus* have been demonstrated to exhibit the property of allelopathy. The allelochemicals produced greatly reduced the chlorophyll content and the cellular respiration of the understory plants. Furthermore, the tree does not allow the germination of the seeds of not only other vegetation but also of its own. The allelopathic effects of Eucalyptus spp on other plants are presented in table 4.

Table 4: Allelopathic effects of *Eucalyptus* spp. on other plants due to its volatile oils

Eucalyptus Spp.	**Effect**
Eucalyptus camaldulensis	Volatile compounds reduces radicle growth of *Bromus rigidus*
Eucalyptus citriodora	Essential oils affect transpiration of sunflower, tomato, bean etc.
Eucalyptus globulus	Volatile compounds from tree inhibit root growth of *Cucumis sativus* seedlings
E. globulus & E. citriodora	Crude volatile oils affect seed grain germination of *Avena sativa, Lens esculentum, Phaseolus vulgare*
E. globulus & E. citriodora	Essential oils absorbed into soil particles affect seed germination and further growth of *Phaseolus aureus*
E. globulus & E. citriodora	The essential oil suppresses seed germination andreduces growth of *Parthenium hysterophorus*

2) Effect of exotics on soil

It is common belief that exotic species in some way cause soil deterioration and sometimes soil sterility. Exotics use excess of nutrients, produce acid soils from accumulation of leaf litter and even they form hardpan, which restrict their planting. One common concept is that continued cropping over several rotations will result in an overall loss in productivity of site. Exotics use heavy nutrients because there is heavy demand from rapidly grown plantations that are harvested at short intervals. Trees planted for short rotation will cause more erosion than long rotation trees when established under identical conditions. The quantity of nutrients removed will be greater, and so, consequently, will be the requirements of fertilizers. Short rotation exotic trees are more likely to cause higher rates of erosion and a greater decline in fertility than long rotation trees.

3) Exotics use an excess of water

One problem commonly associated with growing exotics, particularly *Eucalyptus,* is that exotics use so much water that they create a desert. The high water use of fast growing, evergreen trees can be a concern in areas with a shortage of groundwater on subsurface flows of water. The hydrological impact of fast growing exotics has caused concern to local people in India, especially in semi-arid areas, due to the eucalypts controversy. Consequently, when planning trees in association with crops, it is essential to consider the implications of increased water use on the medium and longer-term water budgets.

Calder *et al* (1997) reported that in southern India, eucalypts plantations not only extract all rainfall that enters the soil, but also utilize an additional 100 mm of water from each metre depth of soil that the roots penetrate. Devi (1983) reported that *Eucalyptus* consumes more water than other trees. According to them the streams feeding agricultural lands in the vicinity of Eucalyptus plantations have gone dry. They also claim that in arid regions the high water uptake by *Eucalyptus* interferes with processes which replenish soil moisture and recharge ground water leading to soil aridisation and ground water depletion. Jhorar *et al* (2008) studied the soil moisture depletion of by *Eucalyptus tereticornis* and *Prosopis cineraria* in semi-arid region. He studied the profile soil moisture at a distance of 1m, 2m and 3m distance from the tree trunk of these two species. He reported that profile moisture was similar in case of *P. cineraria* at all dates and distances, whereas in *Eucalyptus* it increased with distance from tree trunk. The PMS was maximum under control conditions. The final PMS up to 3 m distance was 1.3% and 41.4% lower in *P.cineraria* and *Eucalyptus tereticornis* respectively.

4) Exotics as invasive species

Modern ecology recognizes the problems caused by the invasion of exotic species into native ecosystems and the associated negative effects on patterns of biodiversity (D'Antonio and Meyerson, 2002). The use of exotic species has received increasing attention from their ability to colonize in native ecosystems. Once established, exotic species have the ability to displace or replace native species, disrupt soil nutrients, change the pattern of plant succession, and reduce nearby agricultural crop output (Higman *et al.*, 2005). Invasiveness is characterized by rapid growth rate, efficient dispersal capabilities, large reproductive output and tolerance to a broad range of environmental conditions. Invasive alien species may pose risk to a specific forest species, habitat or ecosystem. One common example is *Lantana camara*, which was introduced as ornamental species but now have become obnoxious weed all over India. The estimated number of invasive plant species in India is known to be around 1400, which occupy an area of 40 million hectares. The main species introduced to India for forestry purposes include Eucalyptus spp, *Acacias*, *Prosopis juliflora* and *Leucaena leucocephala*. Invasiveness has been recorded for *Leucaena leucocephala*, *Prosopis juliflora and Acacia mearnsii.* The weedy nature of *Leucaena leucocephala* is reported from the states of Karnataka, Andhra Pradesh, Tamil Nadu, Punjab and Rajasthan. Whereas *Prosopis juliflora* has weedy nature in states of U.P, Tamil Nadu, Andhra Pradesh, Gujarat, Haryana and Karnataka.

For exotic species the commonly accepted mechanism of invasion is that proposed by Enemy release Hypothesis (ERH), also referred to as the Herbivore escape, Predator escape or Ecological release hypothesis. The Enemy release hypothesis states that "plant species on introduction to an exotic region, experiences a decrease in regulation by herbivores and other natural enemies, resulting in an increase in distribution and abundance". Invasive plants can increase their Competitive ability by modifying the invaded environment. One of the ways this is done is through the production of allelochemicals by invasive plants that inhibit the growth of native plants, also referred as Novel Weapons Hypothesis. For example, *Lantana camara* (Sharma *et al,* 2008)

REFERENCES:

Calder, I. R. (1997). Water use of eucalypts – A review with special reference to South India. *Agric. Water Manage*., **11**:333–342.

Chauhan, S.K., Sharma, S.C., Rajni, C. and Gill, S.S. (2008). Exotics in Indian Forestry. Agrotech Publishing Academy, Udaipur, India

Chellamuthu, V., Balasusbramanian, T.N. and Rajarajan. A. (1997). Allelopathic influence of *Prosopisjuliflora* (Swartz) DC. on field crops. *Allelopathy Journ.* 4(2): 291-302

Chopra, R.K. (2008). Inroduction of exotic species in South India- A boon to paper industry, *Exotics in Indian Forestry*. pp- 103-111

D'Antonio, C., Meyerson, L. (2002). Exotic Plant Species as Problems and Solutions in Ecological Restoration: A Synthesis. *Restoration Ecology*, **10**, 703–713

Davidson, J. (1985). Setting aside the idea that *Eucalyptus* are always bad. Working paper, No. 10, Bangladesh

Del Moral, R. and Muller, C. H. (1969). Fog drip: a mechanism of toxin transport from *Eucalyptus globulus*. *Bull. Torrey Bot. Club*, **96**: 467-75

Del Moral, R. and Muller, C. H. (1970). The allelopathic effects of Eucalyptus camaldulensis. *Amer. Midland Natur*., **83**: 254-82

Devi, M. (1983). Why Eucalyptus? *Economic and Political weekly*. **78**(32): 1379-1381

Dutta and Aggarwal (2003). Restoration of opencast coal mine spoil by planting exotic tree species: a case study in dry tropical region. *Ecological Engineering* **21**:143–151

Food and Agriculture Organization of the United Nations (1985).The ecological effects of Eucalyptus. *FAO Forestry Paper* (No. 59)

Goel, V. and Behl, H.M.(1992). Wood quality for fuel wood rotation cycles. In : IUFRO Conference, Nancy, France.

Harsh, L.N. (2002). Value additions in agroforestry systems for higher economic returns. Abstract national symposium on grass lands and fodder research in the new millennium. Range management society of India, IGFRI, Jhansi, 212p.

Heisey, R. M. 1997. Allelopathy and the secret life of Ailanthus altissima. *Arnoldia (Jamaica Plain)* **57**(3): 28 – 36

Higman, S., Mayers, J., Baas, S., Judd, N., Nussbaum, R. (2005). The Sustainable Forestry Handbook: A Practical Guide for Tropic Forest Managers on Implementing New Standards. Sterling, VA: Earthscan

Jadhav, B. B., and Gaynar, D. G. (1995). Effect of Casuarina equisetifolia J. R. leaf litter leachates on germination and seedling growth of rice and cowpea. *Allelopathy Journ.* **2**:105-108.

Jagger, P. and Pender, J. (2003). The role of trees for sustainable management of less-favored lands: the case of eucalyptus in Ethiopia. *Forest Policy and Economics* **5**(1): 83-95

Jhorar, B.S., Nandal, D.P.S. and Dahiya, R. (2008) Soil moisture depletion by *Eucalyptus tereticornis* and *Prosopis cineraria* in semi-arid regions. Exotics in Indian Forestry. Agrotech Publishing Academy, Udaipur, India.

Kaikini, N.S. (1967). Proc. of the 11^{th} Silvicultural Conference. (1), F.R.I., Dehradun:93 pages

Khajuria, H.N., Dhillon, M.S., Dhillon, D.S., and Dhaliwal, H.S. (1995) Management practices of Eucalyptus in Punjab. Project report submitted to regional centre NAEB Nauni, Solan (H.P), 24p

Kil, B.S., (1992). *Allelopathy: Basic and Applied Aspects*. Chapman & Hall, London, UK. pp. 05-241

Kohli, R.K., Batish, D.R. and Singh, H.P. (1998). *Eucalyptus* oils for the control of *Parthenium hysterophorous* L., *Crop prot.* **17**: 119-122

Luna, R.K. (2006). Plantation Forestry. International Book Distributors, Rajpur Road, Dehradun India.

Mathur, R.S. (1983). Editorial Eucalyptus. *Indian forester* **109**(12)

Moral, D.R. and Muller, C.H. (1970). The Allelopathic effects of *Populus deltoides*, *American midland naturalist* **83**: 254-282

Nasir, H., Iqbal, Z., Hiradate, S., Jujii, Y. (2005). Allelopathic Potential of Robiniapseudo-acacia L. *Journal of Chemical Ecology*¸ **31**, Pages 2179-2192

Pryor, L.D. (1976). The biology of *Eucalyptus.* Edward Arnold, London: pp-77

Rai, P., Handa, A.K. and Uma (2008). Role of exotic species in Agroforestry. Exotics in Indian Forestry. pp- 83-91

Rizvi, S.J.H., Tahir, M., Rizvi, V., Kohli, R.K. and Ansari, A. (1999). Allelopathic interaction in Agroforestry systems. *Crit. Rev plant Sci* **18:** 1773-1796

Sharma, G.P., Raghubansi, A.S., and Singh, J.S (2008). Lantana Invasion: An overview. *Weed Biol. Manag*., 5: 157:165.

Sharma, N.K., Chandran, M and Bhat, J. (2009). Growth performance of three exotic pine species in relation to indigenous species in Uttrakhand Himalayas, India, *Ind. For.* **135:** 1556-1564

Shiva, V. and Bandyopadhay (1987). Ecological audit of *Eucalyptus* cultivation. Research foundation for science and ecology, Dehradun pp-74

Shiva, V. and Bhartwal, J. (2008) Role of exotic species in Agroforestry. Exotics in Indian Forestry. pp- 83-91

Singh, G and Singh, N.T (1993). Mesquite for the revegetation of salt lands. Karnal Central Soil Salinity Research Institute, 24p.

Singh, G. (1996). The Role of *Prosopis* in Reclaiming High-pH Soils and in Meeting Firewood and Forage Needs of Small Farmers. In: Felker, Peter and James Moss (editors). 1996. *Prosopis*: semi-arid fuel wood and forage: tree building consensus for the disenfranchised. A workshop. 13th –15th March, 1996. US National Academy of Science.

Singh, G. (2008). The role of *Prosopis* in reclaiming high pH soils an in meeting fire wood of small farmers. Paper Presented in the International *Prosopis* Workshop in Washington D.C. (USA) March 13-15, pp. 1-27.

Srinivasan, K., Ramasan, M. and Shantha, R. (1990). Tolerance of pulse crops to allelochemicals of tree speies. *Ind. Journ. Of Pulses Res.* **3**:40-44

Sutaria, J.N., Andharia, R. and Patel, V.J. (1986). Thermal power station based on firewood from *Prosopis chilensis* in four talukas of Bhavnagar District. The role of *Prosopis* in wasteland development. Javrajbhai Patel Agro Forestry Centre, Gujarat, India.1–8.

Tewari, D.N. (2003). Bio-fuel to be the future fuel. *Panchatatva darshan* **3**(1):9-12

Tiwari, K.M. (1983). Soil and water conservation-need for better management in the country. *Ind For.* **110** (2): 208