

GROWTH PERFORMANCE OF DIFFERENT PROVINCES OF *AZADIRACHTA INDICA*

A.K. BISARIA, SHIV RAM TYAGI¹ AND MOHAMMAD ABASS AHANGER¹

Forest Research and Extension Centre, Tapovan, Gwalior
E-mail : aksheyb@yahoo.co.in

ABSTRACT

Neem (*Azadirachta indica*) is a multipurpose tree which has been found as core species for desert afforestation in India because it is adapted to tropical and subtropical climates and can tolerate high summer temperatures even up to 50 °C. Present study was conducted on eighteen months old saplings of *Azadirachta indica* procured from different provinces of India and planted in Tapovan, Gwalior in September, 2000. Growth performance viz., plant height, plant girth, flowering percentage and percentage of plant establishment of different saplings has been studied after ten years of initial plantation. Maximum plant height (6.610±0.260 m) has been attained by saplings of Kurnool (A.P.) whereas saplings of Nagpur (Maharashtra) were found to possess maximum plant girth (0.378±0.007 m) after ten years of initial plantation. Better flowering percentage (86.95%) was shown by saplings procured from Hisar (Haryana). After ten years of plantation, saplings of Bhilwara (Rajasthan) have been found with 100% plant establishment percentage and can be considered as better adapted provinces to Tapovan, Gwalior.

Key words: *Azadirachta indica*, Plant height, Plant girth, Flowering percentage.

Introduction

Forest cover is estimated to be about 67.701 million hectares, or 22.8 per cent of the country's land area in India (FAO, 2006). Major plantation species include *Acacia* spp., *Eucalyptus* spp., *Tectona grandis*, *Eucalyptus globulus*, *E. grandis*, *E. tereticornis*, *Acacia auriculiformis*, *A. catechu*, *A. mearnsii*, *A. nilotica*, *A. tortalis*, *Albizia* spp., *Azadirachta indica*, *Casuarina equisetifolia*, *Dalbergia sissoo*, *Gmelina arborea*, *Populus* spp., *Prosopis* spp., *Shorea robusta* and *Terminalia* spp (FAO, 2007). Madhya Pradesh has an area of 94.69 thousand square kilometers (approximately 30.72 per cent of its total geographical area) which happens to be the largest forest cover in the entire country. As per the forest department report, the state has 61.89 thousand square kilometers of reserved forest, 31.10 thousand square kilometers of protected forest and 1.70 thousand square kilometers of unclassified forest (Annual Plan MP Govt. 2010-2011). *Azadirachta indica* (family *Meliaceae*) is a native of the Siwalik deccan parts of South India which grows wild in the dry forests of Andhra Pradesh, Tamil Nadu and Karnataka spreading to Pakistan, Bangladesh, Sri Lanka, Malaysia, Indonesia, Thailand, Middle East, Sudan, Niger, Australia, Africa, Fiji, Mauritius, Central and South America, the Caribbean, Puerto Rico and Haiti (Joy *et al.*, 1998).

Almost every part of neem can be utilized, but seeds are very important as they form raw material for

the growing biopesticide industry. Reforestation of arid area shall prevent soil erosion and economically boost farmer's livelihoods by promoting plantation of fast growing plant species which are adapted to the harsh environment (Zhang, 2005). Plant based pesticides are considered to be more ecofriendly than synthetic pesticides, because of being biodegradable. Neem based pesticide 'Neem-on' has been reported to be less toxic than synthetic pesticide 'dichorous' to fish (Bhat *et al.*, 2012).

Neem is andromonoecious, i.e. bisexual and functional male flowers found on the same tree (Singh *et al.*, 1996) which normally begins to produce flower and seed after 3-5 years of age (Kandaswamy and Raveendaran, 1988; Mahadevan, 1991; Gogate and Gujar, 1993; Gupta *et al.*, 1995). Fifty kg of fruits are annually produced after 10 years of plantation (Tewari, 1992; Chandra, 1997; Ketkar and Ketkar, 1997). Floral initiation occurs in neem during a short period of leaf shedding (Ketkar and Ketkar, 1997). The timing of flowering and fruiting varies from site to site in India (Shanti *et al.*, 1996). The growth of trees has been affected by plants density. Hedge (1993) recommended a spacing of 6x6 m or 8x8 m for neem plantation.

Neem has been found as core species for desert afforestation in Indian desert and is used for supplying food, fodder, fuel, timber, medicine and for providing shade and shelter to desert inhabitants (Gupta, 1995).

Saplings of *Azadirachta indica* procured from Kurnool (A.P.) attained maximum height (6.610 m) whereas saplings from Bhilwara (Rajasthan) showed 100% establishment.

Considerable interest in neem has been generated as a means to prevent the spread of deserts and improve desert environments in Saudi Arabia (Ahmed *et al.*, 1989), sub-Saharan Africa (NRC, 1992) and western India (Gupta, 1994). In view of the role of neem in water harvesting and conservation research on establishment was undertaken in Western India where conditions of low and erratic rainfall, high potential evapotranspiration and high wind speeds prevail (Gupta, 1994; 1995). Bahuguna (1997) has recommended that neem seedlings should be planted in dry areas after the seedlings are more than one year old.

Chaturvedi (1993) has given an extensive overview of use of neem in plantations and for afforestation in India. The ability of the tree to tolerate drought and saline conditions makes the neem tree a good candidate for land restoration. The tree has been shown to improve the fertility of soil and conserve moisture (Tilander and Bonzi, 1997).

International Neem Network (INN) was established in 1994 with the long-term objective to improve the genetic quality and adaptability of neem and to improve its utilization throughout the world (Thomsen and Souvannavong, 1994).

Neem trees are commercially grown to produce azadirachtin which has been promoted as a new 'environment friendly' insecticide because synthetic pesticides adversely affect environment, health and biodiversity (Chamberlain *et al.*, 2000). Mature leaves of neem tree have been used for developing a novel adsorbent for removing dyes from water (Bhattacharyya and Sharma, 2003).

Variation in azadirachtin has been reported by Kaushik *et al.* (2007) in the seeds of neem collected from twelve different states of India as affected by the climate

and habitat.

Material and Methods

Eighteen months old saplings of *Azadirachta indica* were procured from different provinces of India and planted in Forest Research and Extension Centre, Tapovan, Gwalior in September 2000. Saplings of different sources were planted in separate rows. A distance of 4x4 m was maintained between two plants as well as between two rows. Data were recorded after around ten years of plantation. Climatic data such as rainfall, temperature were obtained from the Meteorological Department, Gwalior.

Plant height

Plant height was measured using both direct and indirect methods. Felled trees were measured using linear tape or graduated pole. A range finder (Abney) was used in case of standing trees. The distance from a squatting position to the highest point of the tree crown was measured and calibrated in meters (Arzal and Aliyu, 2010). The distance from the same spot to the tree base was also measured with a measuring tape. Tree height was finally computed using Pythagora's Theorem of right angled triangles (<http://online.anu.edu.au/forestry/mensuration/height.htm>).

$$C = (a^2 + b^2)^{1/2}$$

Where,

- a = the distance to the highest point on the tree crown (hypotenuse)
- b = the distance to the tree base and
- C = the tree height

Plant girth

To determine the d.b.h. (diameter at breast height) the girth at breast height (g.b.h) or circumference of the

Table 1: Climatic data of Forest Research and Extension Centre, Tapovan, Gwalior during last ten years (as per the Meteorological Department, Gwalior)

Month	Mean temperature (°C)		Mean total rainfall (mm)	Mean number of rainy days
	Daily minimum	Daily maximum		
January	15.5	28.3	12.4	0.7
February	18.5	31.5	24.2	1.6
March	22.2	34.9	24.2	1.5
April	25.2	37.3	21.8	1.6
May	26.6	37.9	55.5	3.0
June	26.2	35.4	196.4	10.3
July	25.2	31.7	325.3	15.3
August	25.1	31.4	329.5	15.4
September	24.8	31.7	287.6	13.0
October	23.0	31.4	208.0	8.6
November	18.7	29.8	37.4	1.7
December	15.3	28.0	5.5	0.3
Annual	22.2	32.4	1542.2	73.0

tree was measured by tightly wrapping a tape around the tree main trunk at a height of 1.3m from the ground. The d.b.h was then determined using the mathematical conversions (Arzai and Aliyu, 2010).

$$2 \pi r = X$$

$$r = X/2\pi$$

$$\text{d.b.h.} = 2r = 2X/2\pi$$

Where,

r = radius

X the g.b.h. and $\pi = 3.143$

Flowering percentage

Flowering percentage was calculated as per the formula given below:

$$\text{Flowering \%} = \frac{\text{Plants with flowers}}{\text{Total number of plants}} \times 100$$

Plants established percentage

Established percentage of plants was calculated using the formula:

$$\text{Plants established \%} = \frac{\text{Plants established at present}}{\text{Initially planted saplings}} \times 100$$

Results and Discussion

As per the data of Meteorological Department, Gwalior, mean annual rainfall was recorded 1542.20 mm during last ten years. Average numbers of rainy days have been 73.0. Maximum temperature was observed 32.4°C whereas minimum temperature was 22.2°C during last ten years (Table 1).

Performance with respect to plant height, plant girth, flowering percentage and percentage of plant established (survival percentage) often years old plants of *Azadirachta indica* procured from different provinces of India and planted in Forest Research and Extension Centre, Tapovan, Gwalior exhibited variation. Saplings procured from Kurnool (A.P.) attained maximum plant height i.e. 6.610±0.260 m whereas saplings of Dharwad (Karnataka) were found to possess minimum plant height i.e. 4.200±0.070 m (Table 2).

Table 2: Growth parameters of *Azadirachta indica* (eighteen months old saplings procured from forest nurseries of different sites) ten years after plantation in Forest Research and Extension Centre, Tapovan, Gwalior

S. No.	Town and province of species from which saplings have been procured	Plant height (m)	Plant girth (m)	Flowering per cent
1	Nizamabad (A.P.)	3.620±0.252	0.232±0.019	28.57
2	Mehbub Nagar (A.P.)	5.480±0.173	0.300±0.008	71.42
3	Kurnool (A.P.)	6.610±0.260	0.350±0.006	66.66
4	Praksham (A.P.)	6.210±0.197	0.340±0.009	68.75
5	Nagpur (Maharashtra)	5.660±0.149	0.378±0.007	45.00
6	Nasik (Maharashtra)	6.100±0.127	0.280±0.006	60.00
7	Aurangabad (Maharashtra)	5.510±0.087	0.324±0.004	50.00
8	Nanded (Maharashtra)	6.120±0.118	0.330±0.006	50.00
9	Yavatmal (Maharashtra)	5.700±0.096	0.285±0.005	73.07
10	Hisar (Haryana)	5.530±0.085	0.317±0.004	86.95
11	Dharwad (Karnataka)	4.200±0.070	0.203±0.004	45.45
12	Jodhpur (Rajasthan)	4.820±0.085	0.257±0.004	32.00
13	Bhilwara (Rajasthan)	4.770±0.082	0.226±0.006	17.39
14	Bhopal (M.P.)	5.090±0.096	0.275±0.004	71.42
15	Hoshangabad (M.P.)	4.710±0.073	0.227±0.004	48.00
16	Chindwara (M.P.)	5.770±0.091	0.257±0.003	55.56
17	Seoni (M.P.)	4.940±0.044	0.238±0.004	55.56
18	Palanpur (Gujarat)	4.760±0.083	0.282±0.005	21.05
19	Palanpur (Gujarat)	4.780±0.053	0.273±0.003	56.00
20	Palanpur (Gujarat)	5.770±0.083	0.280±0.004	47.20
21	Jalgaon (Maharashtra)	5.630±0.060	0.344±0.004	52.38
22	Jelana (Maharashtra)	6.230±0.080	0.348±0.005	66.66
23	Warangal (A.P.)	6.190±0.117	0.302±0.005	46.67
24	Krishana (A.P.)	6.340±0.300	0.356±0.012	55.55
25	Chandrapur (Maharashtra)	5.760±0.180	0.300±0.012	37.50
26	Parbani (Maharashtra)	6.400±0.282	0.376±0.008	55.55
27	Gwalior (M.P.)	4.900±0.247	0.270±0.012	28.57

However, saplings taken from Praksham (A.P.), Nasik (Maharashtra), Nanded (Maharashtra), Jalana (Maharashtra), Warangal (A.P.) and Parbani (Maharashtra) were also found suitable for plantation in environs of Tapovan, as per the growth data recorded (Table 2).

Eighteen months old saplings taken from Nagpur (Maharashtra) were found to possess maximum plant girth (g.b.h.) i.e. 0.378 ± 0.007 m whereas saplings of Dharwad (Karnataka) were found less adapted to Tapovan region as observed after ten years of initial plantation (Table 2). Although saplings procured from Mehbub Nagar (A.P.), Praksham (A.P.), Aurangabad (Maharashtra), Nanded (Maharashtra), Jalgaon (Maharashtra), Jalana (Maharashtra), Warangal (A.P.), Chandrapur (Maharashtra) and Parbani (Maharashtra) also exhibited good response (Table 2).

Maximum flowering percentage i.e. 86.95% has been reported in saplings of Hisar (Haryana) whereas minimum flowering percentage of 17.39% was found in saplings procured from Bhilwara (Rajasthan) (Table 2). Nevertheless, saplings of Mehbub Nagar (A.P.), Yavatmal

(Maharashtra) and Bhopal (M.P.) also showed good flowering (Table 2). Percentage of plants established (plants survival percentage) with respect to initial plantation, saplings of Bhilwara (Rajasthan) was hundred per cent indicating that they are adapted to climates of Tapovan, Gwalior. However, saplings of Hisar (Haryana), Jodhpur (Rajasthan), Palanpur (Gujarat) and Jalgaon (Maharashtra) have also been found good for Gwalior region (Table 3).

It was found that 651 saplings were initially planted into Tapovan and after ten years of plantation, only 489 plants survived which means an overall reduction of 24.88% in total saplings of *Azadirachta indica* with respect to initial plantation. Earlier also some of the reports are available from different regions. The tree height, collar diameter, dbh, clear bole length and canopy diameter of 13-year-old trees grown at CAZRI, Jodhpur, India were assessed for variation in growth characteristics (Jindal *et al.*, 1999). Fruit and seed characteristics, e.g. weight, length, width, diameter, yield and azadirachtin and oil content are highly variable in neem (Kumaran *et al.*, 1993; Sridharan *et al.*, 1998; Jindal

Table 3: Percentage of plants established of *Azadirachta indica* ten years after plantation in Forest Research and Extension Centre, Tapovan, Gwalior from different provinces of India

S.No.	Town and province of species from which saplings have been procured	Saplings planted	Plants established	Percentage of plants established with respect to initial plantation
1	Nizamabad (A.P.)	18	07	38.89
2	Mehbub Nagar (A.P.)	18	14	77.78
3	Kurnool (A.P.)	27	16	59.26
4	Praksham (A.P.)	27	16	59.26
5	Nagpur (Maharashtra)	27	20	74.08
6	Nasik (Maharashtra)	24	20	83.34
7	Aurangabad (Maharashtra) Maharashtra	26	22	84.62
8	Nanded (Maharashtra)	27	24	88.89
9	Yavatmal (Maharashtra)	31	26	83.88
10	Hisar (Haryana)	25	23	92.00
11	Dharwad (Karnataka)	27	22	81.49
12	Jodhpur (Rajasthan)	27	25	92.60
13	Bhilwara (Rajasthan)	23	23	100.00
14	Bhopal (M.P.)	25	21	84.00
15	Hoshangabad (M.P.)	30	25	83.34
16	Chindwara (M.P.)	22	18	81.82
17	Seoni (M.P.)	25	18	72.00
18	Palanpur (Gujarat)	22	19	86.37
19	Palanpur (Gujarat)	26	25	96.16
20	Palanpur (Gujarat)	25	21	84.00
21	Jalgaon (Maharashtra)	20	18	90.00
22	Jalana (Maharashtra)	25	18	72.00
23	Warangal (A.P.)	27	15	55.56
24	Krishana (A.P.)	20	09	45.00
25	Chandrapur (Maharashtra)	25	08	32.00
26	Parbani (Maharashtra)	20	09	45.00
27	Gwalior (M.P.)	12	07	58.34

et al., 1999). Similar results have also been reported by Kumaran et al. (1993) who found significant differences between populations of neem from Tamil Nadu, India. Variation in fruit yield per tree, 100-fruit weight, 100-seed weight, 100-kernel weight and oil content in 13-year-old neem trees from Jodhpur, India has been recorded and analysed by Jindal et al. (1999).

The annual production of biomass in neem was reported to be between 3 and 10 m³ per ha (Hedge, 1991) which justifies its categorization as a medium fast growing tree. A study conducted in western Rajasthan showed that growth is fast in the first ten years and later it slows (Tewari et al., 1996). 66% of the total growth of neem trees occurred within the first three years of plantation (Radwanski, 1977) attaining a height of approximately 4-7 m after three years and height between 5-11 m after five years. Rate of growth, however, being influenced by site conditions. Variation in quantitative phenological parameters like leaf, flower, fruit abundance, leaf area etc of *Azadirachta indica* A

Juss (neem) for Narmada valley, Vain ganga valley and Satpura plateau has been described by Pande et al. (2004). Screening of provenances of neem on the basis of azadirachtin, oil content in the seeds from twelve agro-climatic zones of central India has been carried out by Jain and Banerjee (2010).

Conclusion

A variation in plant height, plant girth, flowering percentage and plants established percentage has been observed in saplings procured from different provinces. The saplings obtained from tropical climates have been found to exhibit better flowering percentage whereas saplings of Andhra Pradesh and Maharashtra showed maximum plant height and girth. However, an intensive research should be undertaken to screen/ develop more tolerant and resistant varieties of neem for tropical environment. New approaches such as hybridization, genetic recombination, plant tissue culture etc. may also be employed for genetic and physiological improvement of saplings of *Azadirachta indica*.

Acknowledgement

Authors are thankful to Prof. R.M. Agarwal, Former Dean, Life Sciences, School of Studies in Botany, Jiwaji University, Gwalior for his valuable suggestions and kind support during the course of work and the Meteorological Department, Gwalior for providing climatic data.

अजाडिराक्टा इन्डिका के विभिन्न उद्गम स्थलों की वृद्धि निष्पादकता

ए.के. बिसारिया, शिव राम त्यागी तथा मुहम्मद अब्बास अहंगर

सारांश

नीम (*अजाडिराक्टा इन्डिका*) एक बहुउद्देशीय वृक्ष है जो भारत के रेगिस्तान में वनीकरण के लिए महत्वपूर्ण प्रजाति है। यह वृक्ष उष्ण कटिबंधी तथा उप-उष्णकटिबंधी जलवायु में अनुकूलित है और गर्मियों में 50 डिग्री सेल्सियस के तापमान को सहने में सक्षम है। वर्तमान अध्ययन नीम के 18 स्थानों पर उगने वाले वृक्षों पर किया गया। जिनमें भारत के विभिन्न उद्गम स्थलों से प्राप्त करके सितम्बर 2000 में तर्पोवन, ग्वालियर में रोपित किया गया था। प्रारंभिक रोपण के 10 वर्षों बाद विभिन्न बाल वृक्षों की वृद्धि निष्पादकता अर्थात् पादप की ऊँचाई, व्यास, पुष्पन प्रतिशत और स्थापित होने की प्रतिशतता का अध्ययन किया गया। करनूल (आंध्र प्रदेश) के बाल वृक्ष ने सर्वाधिक ऊँचाई (6.610 ± 0.260 एम) प्राप्त की। जबकि प्रारंभिक रोपण के 10 वर्षों बाद नागपुर (महाराष्ट्र) के बाल वृक्ष की पादप क्षमता (0.378 ± 0.007 एम) थी। तिसार (हरियाणा) से प्राप्त बालवृक्ष की पुष्पन क्षमता उच्चतम (86.95 प्रतिशत) रही। रोपण के दस वर्षों बाद भी लखड़ा (राजस्थान) के बालवृक्षों का स्थापन प्रतिशत 100 प्रतिशत रहा और इसे तर्पोवन ग्वालियर के उद्गम स्थल के बराबर अनुकूलित माना गया।

References

- Ahmed S., Bamofleh S. and Munshi M. (1989). Cultivation of neem (*Azadirachta indica*, Meliaceae) in Saudi Arabia. *Economic Botany*, **43**: 35-38.
- Annual Plan (2010-2011). Volume-1. Government of Madhya Pradesh. Planning, Economics and Statistics Department, 1-340 pp.
- Arzal A.H. and Aliyu B.S. (2010). The relationship between canopy width, height and trunk size in some tree species growing in the Savana zone of Nigeria. *Bayero Journal of Pure and Applied Sciences*, **3**(1): 260-263.
- Bahuguna V.K. (1997). Silviculture and management practices for cultivation of *Azadirachta indica* (neem). *Indian Forester*, **123** (5): 379-386.
- Bhat B.A., Bhat I.A., Viswakarma S., Verma A. and Saxena G. (2012). A comparative study on the toxicity of a synthetic pesticide, Dichlorvos and neem based pesticide, Neem-On to *Labeo rohita* (Hamilton). *Current World Environment*, **7**(1): 157-161.
- Bhattacharyya K.G. and Sharma A. (2003). Absorption characteristics of the dye, brilliant green on neem leaf powder. *Dyes and Pigments*, **57**: 211-222.
- Chamberlain J.R., Childs F.J. and Harris P.J.C. (2000). An introduction to neem, its uses and genetic improvement, Department for International Development (DFID), UK.

- Chandra V. (1997). Botany of neem, *Annals of Forestry*, 5(2): 182-188.
- Chaturevedi A.N. (1993). Silviculture in Neem Research and Development, (eds.) N.S. Randhawa and B.S. Parmar. Society of Pesticide Science, India, 38-49 pp.
- F. A. O. (2006). *Global Forest Resources Assessment 2005 – progress towards sustainable forest management*, F. A. O., Rome.
- F. A. O. (2007). *Overview of forest pests - India. Forestry paper FBS/18E*. F. A. O., Rome, Italy.
- Gogate M.G. and Gujar D.R. (1993). An assay of genetic variability through phenological studies on a neem (*Azadirachta indica* A. Juss.) plantation. In: *Proceedings of the World Neem Conference 1993*, Bangalore, India, 132-137 pp.
- Gupta G.N. (1994). Influence of rain-water harvesting and conservation practices on growth and biomass production of *Azadirachta indica* in the Indian desert, *Forest Ecology and Management*, 70: 329-339.
- Gupta G.N. (1995). Rain-water management for tree planting in the Indian Desert, *Journal of Arid Environments*, 31: 219-235.
- Gupta P.K., Pal R.S. and Emmanuel C.J.S.K. (1995). Initial flowering and fruiting of the Neem National Provenance Trial, *Indian Forester*, 121 (11): 1063-1068.
- Hedge N.G. (1991). BAIF Research and Development Foundation, Pune, India.
- Hedge N.G. (1993). Improving the productivity of neem trees. World Neem Conference, Bangalore, India, 69-79 pp.
- Jain A. and Banerjee S.K. (2010). Screening of superior provenances of *Azadirachta indica* A. Juss. in Central India through azadirachtin, oil and fatty acid content in the seeds, *Ecology, Environment and Conservation Paper*, 16(2): 229-234.
- Jindal S.K., Vir S. and Pancholy A. (1999). Variability and associations for seed yield oil content and tree morphological traits in neem (*Azadirachta indica*), *Journal of Tropical Forest Science*, 11: 320-322.
- Joy P.P., Thomas J., Mathew S. and Skaria B.P. (1998). Medicinal plants. Aromatic and Medicinal Plants Research Station, Kerala Agricultural University, Kerala, 56p.
- Kandaswamy A. and Raveendran N. (1988). Productivity of neem trees in Tamil Nadu, India—An observational study. Paper presented at the Final Workshop of the IRRI-ADB-EWC Project on Botanical Pest Control in Rice-based Cropping Systems. IRRI, Los Banos, Philippines. 10 pp.
- Kaushik N., Singh B.G., Tomar U.K., Naik S.N., Vir S., Bisla S.S., Sharma K.K., Banerjee S.K. and Thakkar P. (2007). Regional and habitat variability in azadirachtin content of Indian neem (*Azadirachta indica* A. Jussieu), *Current Science*, 92(10): 1400-1406.
- Ketkar C.M. and Ketkar M.S. (1997). Botany. In: *Neem in Sustainable Agriculture*, (Narwal S.S., Tauro P. and Bisla S.S.). Scientific Publishers, Jodhpur, India. 1-12 pp.
- Kumaran K., Surendran C. and Rai R.S.V. (1993). Variation studies and heritable components of seed parameters in neem (*Azadirachta indica* A. Juss.). In: *Proceedings of the World Neem Conference 1993*, Bangalore, India, 167-173 pp.
- Mahadevan N.P. (1991). Phenological observations of some forest tree species as an aid to seed collection, *Journal of Tropical Forestry*, 7 (3): 243-247.
- National Research Council (1992). *Neem: A tree for solving global problems*, National Academy Press, Washington D.C., USA, 141 pp.
- Pande P.K., Singh J., Mesram P.B. and Pal M. (2004). Phenological studies on *Azadirachta indica* A. Juss. (neem) of Satpura and adjacent agro-climatic zones of Madhya Pradesh (India), *Indian Forester*, 130 (3): 273-282.
- Radwanski S.A. (1977). Neem tree IV. A plantation in Nigeria, *World Crops Livestock*, 29: 222.
- Shanthy K., Manimuthu L. and Singh B.G. (1996). Genetic significance of late flowering forms in neem (*Azadirachta indica* A. Juss.) as reflected by germination studies, *Indian Forester*, 122(3): 263-264.
- Singh V.P., Dhillon R.S. and Jhorar B.S. (1996). Floral biology, breeding behaviour and breeding strategy in neem (*Azadirachta indica* A. Juss.). In: *Proceedings of the International Neem Conference*, University of Queensland, Australia.
- Sridharan S., Venugopal M.S., Dhaliwal G.S., Arora R., Randhawa N.S. and Dhawan A.K. (1998). Effect of environmental conditions on the yield of azadirachtin and oil in neem. In: *Ecological agriculture and sustainable development: Volume 1*. Indian Ecological Society and the Centre for Research in Rural and Industrial Development, Chandigarh, India, 510-518 pp.
- Tewari D.N. (1992). *Monograph on neem (Azadirachta indica A. Juss.)*. International Book Distributors, Dehradun, India, 279 pp.
- Tewari V.P., Jain R. C., Kumar S. and Kumar V. S. K. (1996). Growth statistics of neem in arid areas of western Rajasthan, *Journal of Non-Timber Forest Products*, 3: 1-2.
- Thomsen A. and Souvannavong O. (1994). The International Neem Network. Forest Genetic Resources 22, FAO, Rome.
- Tilander Y. and Bonzi M. (1997). Water and nutrient conservation through the use of agroforestry mulches and sorghum yield response, *Plant and Soil*, 197: 219-232.
- Zhang Y. (2005). The introduction and domestication of *Azadirachta indica* in dry hot valleys of China. World Forestry Centre, Portland.