PLANT GENE & TRAIT
2014, Vol. 5, No.2, 11-21 http://pgt.sophiapublisher.com

Research Report Open Access

Caesalpinia sappan L: Comprehensive Review on Seed Source Variation and Storability

N. Mariappan, S. Krishnakumar, S. Ramesh Kumar, K. Krishna Surendar
Vanavarayar Institute of Agriculture, Manakkadavu, Pollachi -642103, India
Correspondings author, mariappann21@gmail.com; Authors
Plant Gene and Trait, 2014, Vol.5, No.2 doi: 10.5376/pgt.2014.05.0002

Abstract *Caesalpinia sappan* is widely used in traditional medicine and chemical investigation resulted in the isolation of novel and interesting phytochemicals possessing potent biological properties. The most successful tree improvement programme is that where proper seed sources were used. The loss from using the wrong sources can be great and even disastrous. *Caesalpinia sappan* is commonly propagated through seeds. The present review discusses the seed source variation and increase the seed longevity in suitable storage techniques. The wood *Caesalpinia sappan* has already proved export quality of natural dye and it has the potential to become a drug to enter into the world market due to its interesting biological effects and vast folklore uses is worth that might provide a rich natural resources. In future, more basic research is needed to elucidate the mechanism to appraise the better seed source variations and seed storage behaviuor and techniques in *Caesalpinia sappan.*

Keywords *Caesalpinia sappan*; Seed source; Variation; Storage

Background

The blooming demands for natural food colouring products as well as the expansion of green cover could only be achieved by introducing dye yielding trees in plantation forestry (Buchanan, 1999). *Caesalpinia sappan* is one of the versatile natural dye yielding trees that can be grown on a large scale in tropical areas (Chennagowda et al., 2001). Cultivation of *Caesalpinia sappan* serves three purposes *viz.*, to enable the country to march towards meeting the natural dye demands, greening of environment and sequestering atmospheric carbon a popular logo of the global concern at present (Holmgren et al., 2003). It is an important dye plant attaining economic importance in recent years (Kurain & Sankar, 2007). The important part of this plant is the heart wood that contains water soluble dyes such as brazilein, protosappanins, sappan chalcone and haematoxylin. In recent times the dye is used for natural colouring of food products, beverages, and pharmaceuticals (*Senthilkumar* et al., 2011).

The economical part of the plant is obtained by extraction of heart wood. Sappan yields different shades of red with or without mordant (Siva, 2007). The yield of sappan heartwood dye has been reported as up to 20% of the heart wood on a moisture free basis (Jansen, 2005). The heart wood is often first reduced to a powder moistened and is then allowed to ferment, there by encouraging oxidation of the brazilein and the other natural pigments. The aqueous extract is concentrated prior to use as a dye. Brazilian on oxidation yield a red dye called brazilein- the most valuable dye used in colouring leather, silk, cotton, wool and fibres of different kinds, calico printing, batik, food products, pharmaceuticals and wines (Roecklein and Leung, 1987). More commonly this natural dye has been used in mat industries in some parts of Tamil Nadu, India, where the fibers obtained from sedges, korai) are coloured by sappan dye (Benazir et al., 2010).

The wood is used in carpentry, the timber, which has straight grains, is of great value under the name of pernambuco for making violin bows (Smartt, 1990). The wood is orange red, hard, very heavy, Weight: 1,030 kg m^{-3}, Air dry) straight grained with a fine and even texture. It is suitable for cabinet making, walking sticks and small ornamental turnery articles like dagger sheaths and hilts (Jansen, 2005). The pods contain 40% tannin and can be used in the place of sumac. They impart uniform tan and a soft touch to

PLANT GENE AND TRAIT

Preferred citation for this article:
Mariappan, 2014, *Caesalpinia sappan* L: Comprehensive Review on Seed Source Variation and Storability, Plant Gene and Trait, Vol.5, No.2 11-21 (doi: 10.5376/pgt.2014.05.0002)
Received: 03 Sep., 2013 | Accepted: 06 Dec., 2013 | Published: 04 Jan., 2014

the leather. The seeds on extraction with petroleum ether yield an orange coloured fixed oil (Shahid and Mohammad, 2013), An infusion of the wood is a powerful astringent and emmenagogue. It is prescribed in atomic diarrhaea and dysentery and its paste in rheumatism, haemorrhages to treat wounds (Khatun and Rahman, 2006).

In spite of these attractive features, the tree species suffers from a drawback i.e., it is low viability. The basic objective/aim of a tree improvement programme are to select a better seed source for propagation (Zobel and Talbert, 1984). Delineation of the best seed sources for individual species in an important milestone in establishing a successful population of trees. Hence, there arises an urgent need for exploiting the best seed source for propagation potential, (Umarani et al., 1997; Vijayaraghavan, 2000). But the available information on the existing seed sources and its storage techniques is not sufficient.

The longevity of seed in storage is also largely influenced by the genotypes, history of seed taken into storage, moisture content of seed, container in which it is packed and temperature of storage environment (Fairey et al., 1999). Large scale production of good quality seed requires storage for more than one season. If not properly guarded, seed material will rapidly deteriorate and completely loose its viability in short time. The knowledge on storage potential of seeds is essential for effective seed management (Merritt and Dixon, 2011). In *Caesalpionia sappan* the seed production, collection and storage in perennial tree species is highly influenced by environmental factors and quality seed collected could be used as source material for many a plantation.

2 Botanical Classification

Kingdom: Plantae; Division: Magnoliophyta; Class: Magnoliopsida; Order: Fabales; Family: Fabeaceae; Genus: Caesalpinia; Species: Sappan.

Botanical Name: *Caesalpinia sappan Linn.*

Synonyms: *Biancaea sappan*

Common Names:

English: I ndian redwood, Sappan wood, Brazil wood; Hindi: Patamg, Bakam; Sanskrit: Patrangah, Patangah; Kannada: Sappange; Malayalam: Chappannam, Sappannam; Marathi: patang, pathang; Tamil: Sappamgu, Patamgam; Telugu: Bakaruchakka

3 Documented species distribution

Native: Native to Southeast Asia and the Malay Archipelago, China, India, Malaysia, Myanmar, Thailand.

Exotic: Indonesia, Papua New Guinea, Philippines, Solomon Islands, Sri Lanka, Taiwan, Province of China, United States of America.

4 Ecology

Under natural conditions *C. sappan* grows mostly in hilly areas with clayey soil and calcareous rocks at low and medium altitudes. In Peninsular Malaysia it grows best on sandy riverbanks. It does not tolerate too wet soil conditions (Orwa et al., 2009).

5 Botanical description

General morphology: *Caesalpinia sappan* is a small to medium-sized, shrubby tree, 4-8, -10) m tall; trunk up to 14 cm in diameter; bark with distinct ridges and many prickles, greyish brown; young twigs and buds hairy, brownish (Troup, 1921).

Root: the root is fibrous, from white to reddish, odourless; with saffron bark, covered with a black skin.

Leaves: stipulate, bipinnate, alternate, 20~45 (~50) cm long, 10~20 cm broad, with 8~16 pairs of up to 20 cm long pinnae; pinnae with prickles at the base and with 10~20 pairs of oblong, 10~20 mm×6~10 mm long, subsessile leaflets, very oblique at base, rounded to emarginated at apex.

Flowers: flowers in terminal panicles, racemes pubescent, primary penducles 30~40 cm long, the flowering 9~15 cm long, bracts ovate-acuminate, about 6 mm long, flowers fragrant, 2~3 cm long, 5-merous; sepals glabrous, petals pubescent, the superior one smaller; calyx tube 3 mm long; corolla yellow, uppermost lobes cuneate, other obovate, all clawed and gland-punctate; stamens 10, filaments densely tomentose in the lower half; ovary superior, pubescent, (Kirtikar & Basu, 1989).

Fruit and seeds: fruit a dehiscent pod, glabrous, thick, flattened, obliquely oblong, prominently beaked, woody, polished-brown, 7-10 cm x 3-4 cm, 2-3(-5) seeded. Seeds are ellipsoid, flattened, 18-20 mm x 10-12 mm, brown (Warriers et al., 1993).

6 Phenology

The species flowers during May. Mature pods can be collected from January to February (Talavero, 1992).

7 Biology

Flowering can occur after 1 year of growth and usually during the rainy season, fruiting about 6 months later. The tree flowers in August in Myanmar and in Indonesia pods are produced 13 months after planting (Orwa et al., 2009).

8 Influence of Seed Source Variation

Agro-ecological conditions mostly comprises of edaphic and environmental factors have more than one effect on the performance of the resultant seeds and he also stresses the possibility, that seeds are always remembered by their place of birth (Heydecker 1972; Kjaer and Foster, 1996; Lacaze, 1978) expressed that better growth, quality and adaptability could be achieved through careful selection of the best sources and raising trees seedlings from the selected source in any plantation programme. They also insisted that the choice of seed source is important since it decides the genetic quality and physiological potential of the seed. Allen and Allen (1981) evaluated the seed source variation in seed and seedling traits of several tree species under controlled conditions and revealed that the phenotypical values were closer to genotypical values when the environmental deviations are being negligible. They also added that apart from genetic factors, the initial germination of seed is also influenced by the seed source.

Seed source variation on seed and seedling quality characters

Out of 15 different *Caesalpinia sappan* sources from Tamil Nadu and Kerala states of India, the Pariyaram seed source exhibit highest germination per cent and other seedling quality characteristics (Arthanari 2008). The seed source variation in *Acacia catechu* revealed that among the different seed sources, the seed length varied from 7.79 mm to 10.41 mm and seed width from 6.06 to 8.84 mm, while Rajapura seed source excelled all other seed sources for seed length and width. They also found that 100 seed weight varied from 76.95 to 17.89 g and Nauni and Chakla seed sources were observed to possess the highest and lowest average 100 seed weight (Bhat and Chauhan, 2003).

In *Bixa Orellana* (Nelsonnavamaniraj, 2005) reported that the seed source variation based on physical, image analysis, 100 seed weight), physiological, germination, root length, shoot length, dry matter production, vigour index and electrical conductivity) characters of seed and dye content expressed that seeds of Avinashi from Tamil Nadu and Chindwara of Madhya Pradesh performed better than the evaluated seed sources *viz.*, Avinashi, Gudallore, Tirunelveli, Sirikakulam, Mysore, Bangalore, Wayanad, Chindwara and hence these sources could be recommended for collection of good quality seeds.

Dwivedi (1993) observed a wide variation in the germination of neem seeds collected from different provenance in India. He also reported that pungam seeds collected from different sources recorded greater variation for seed size and seed shape. Surendran et al (1993) identified one hundred and forty nine plus trees in neem using straightness of bole, intensity of branching, crown spread, fruit bearing efficiency and fruit yield as selection criteria and evaluated for length, width, 100 seed weight, germination per cent and oil content. One hundred seed weight ranged from 17.4 to 29.5 g. According to Mishra et al (1997) neem seed collected from five different states exhibited wide variations for the germination and seed morphological parameters. Seeds from Kanpur, UP) recorded maximum seed breadth while seeds from Karnataka state excelled for other parameters. Philomina (2000) examined seeds of neem and reported significant variations among 73 one-parent families in respect of seed characters *viz.*, seed length, seed breadth, seed length to breadth ratio and 100 seed weight.

Vakshasya et al (1992) measured ten seed and seedling characters of *Dalbergia sissoo* population on samples collected throughout the natural range of the species in India and observed the existence of significant genetic variations for the seed and seedling traits. Jenner

(1995) reported distinct variation among the 23 one-parent families of *Madhuca latifolia* in respect of seed characters *viz.,* seed length, seed breadth, seed length: seed breadth ratio and 100 seed weight. Seed length varied between 3.92 cm and 2.16 cm, seed breadth from 0.94 cm to 1.35 cm, seed length: seed breadth ratio from 0.94 to 1.35 and 100 seed weight between 134.06 g and 262.04 g. The germination capacity and growth of seedlings also influence by the seed sources. Such variations were evident in *Madhuca latifolia* (Umesh Kanna, 2001).

Significant variation among the seed sources in respect of viability and vigour in storage in both teak drupe and sandal seed (Manonmani, 1997; Mahadevan et al., 1999) carried out an experiment to elucidate the relationship of cone and seed traits of *Casuarina equisetifolia* with 18 seed lots by measuring seed surface area, length, breadth, 100 seed weight, roundness and aspect ratio using image analyzer and observed wide variations in cone and seed characters**.**

An investigation involving different seed sources of *Acacia nilotica* was taken up by Vanangamudi et al (1998), Vijayaraghavan (2000) and Venkatesh (2000) to evaluate the physical qualities of seed *viz.,* seed length, breadth, thickness and 100 seed weight and they expressed that significant variation in physical characters were exhibited with the evaluated seed sources. Kumar et al (2003) concluded that variation in seed characteristics of *P. cineraria* could be attributed to mother tree differences and as the result of wider variation in climatic conditions in areas of its natural distribution. Similarly Kumar et al (2003) reported that out of the six locations of *Pongamia pinnata* in Tamil Nadu, the seed weight was the highest in Salem seed lot followed by Pillur and Erode, while the lowest was in seeds of Karur. The number of seeds per kilogram was highest in seeds of Karur followed by Coimbatore and lowest in Salem. It was found that moisture content varied significantly among the seeds varied from 6.3% in Salem to 5.3% in Karur seed source.

Variation in seed parameters and germination of *Jatropha curcas* were noticed in the seeds collected from ten different seed sources by Kumar et al (2003), and they reported that the germination and vigour index values were the highest with seeds of Walayar and while the least was with Paripati seed source. Similar seed source variation studies were conducted with seeds of different location of collected from Tamil Nadu and Kerala in *Jatropha curcas* by Kumar et al (2004a; 2004b) and the seeds were found to exhibit variation in seed size, weight and germination. Geethanjali et al (2004) also observed variation in seed size, weight, oil content and germination in large, medium and small sized seed of *Jatropha curcas*. Ginwal et al (2005) collected ten seed sources of *Jatropha curcas* and expressed that they exhibited considerable variability in seed morphological tracts *viz.,* seed length, seed width, germination per cent and oil content.

Large variations in seed morphological characters among different seed sources were also observed in *Bassia latifolia* (Jenner, 1995; Umeshkanna, 2001), *Dalbergia sissoo* (Vakshasya et al., 1992), *Emblica officinalis* (Srimathi, 1997); *Grewia optiva* (Tyagi et al., 1999); *Pongamia pinnata* (Sivasamy, 1991; Kumaran 1991), *Prosopis cineraria* (Arya et al., 1992; Bahadur and Hooda, 1995), *Santalum album* (Sindhuveerendra et al., 1999), *Syzygium cuminii* and *Zizyphus mauritiana* (Srimathi, 1997); *Tectona grandis* (Parthiban, 2001); *Tamarindus indica* (Divakara, 2002)

Krishnan and Toky (1996) observed variation in germination among twelve seed sources of *Albizzia lebbeck* from India and among the sources, the germination varied from 5%~ 94% in incubator and 8%~50% at nursery. Bhat and Chauhan (2003) reported that the germination of *Albizzia lebbeck* varied from 16%~38% and the seeds from Nalgarh recorded the highest germination per cent, 38%, They also suggested that seed sources that produce heavier seeds possessed higher germination per cent than that locations that produce smaller seeds.

Lavania and Virendrasingh (2004) reported that the germination of *Populus ciliata* from different seed sources differed significantly with one another and the germination ranged from 42% (Kathpudia seed source) to 72%, Nainital seed source (Kumar et al., 2003a) confirmed that the higher germination and seedling development of *J. curcas* were observed in the heavier seed than in the lower seeds irrespective of the location. It was also observed that germination and vigour index values were the highest in Walayar seed source and the least in Paripatti seed source. Whereas, germination of *J. curcas* varied from 82%, 73% and 49% in large, medium and small seeds respectively in Madurai seed source and 65%, 58% and 37% in Palani seed sources respectively (Sivasamy, 1991) reports the impact of seed source variations in seed germinability, vigour and biochemical composition in neem. The germination capacity and growth of seedlings was also reported to be influence by the seed sources. Significant difference in germination and growth were observed in seedlings of *Azadirachta indica* (Mani 2000).

9 Estimation of Variability, Heritability and Genetic Advance

Heritability estimation in conjunction with genetic advance is more useful in predicting the resultant effect of selecting the best individual from population (Johnson et al., 1955). Heritability estimates have an important place in tree breeding as they provide an evaluation of the relative strengths of genetic and environmental influences. Further, they are also useful for ranking the trait in cross breeding programme. It is the proportion of total variability, which is due to heredity, the remainder being due to environmental causes (Zobel and Talbert, 1984). Gains from tree breeding programme depend upon the type and extent of genetic control and variability. The best gains are made for characteristics that are strongly under genetic control and have a wide range of variability. Heritability combined with genetic advance can be used as a very good selection index for tree improvement programme (Zobel, 1971).

Higher rates of heritability and genetic advance were recorded for all characters among twelve provenances of *Acacia nilotica* (Ginwal et al., 2000). Seeds of *Azadirachta indica* collected from different places in Karnataka and Andhra Pradesh recorded higher genetic variability for seed length, width and seed weight (Sindhu, 1995). A good amount of genetic variability of seed morphological parameters was recorded in *Azadirachta indica*. Philomina (2000) reported that shoot length, root length, root shoot ratio, collar diameter, number of leaves, total dry weight and oil content, recorded high phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance (GA) as percentage mean in *Azadirachta indica*.

Higher heritability was reported for three growths attributes *viz.*, height, collar diameter and leaf number and low heritability for physiological parameters in four species and twelve hybrids of *Eucalyptus* (Paramathma et al., 1997), In *Prosopis cineraria* (Solanki et al., 1984) reported that heritability increases with increasing age for plant height where in heritability was 46.6% in first year and 85.2% in 5th year. Chopra and Hooda (2001) reported that in *Prosopis juliflora* the high heritability recorded for all the growth parameters and also high genetic advance was observed for dehydrogenous activity, germination percentage, root length, seedling length and vigour index I and II.

Ginwal et al (2004) evaluated seed sources of *Jatropha curcas* and the growth performance from nursery stage (three months to field, two years) revealed that significant differences between the seed sources at age 27 months were observed for height, collar diameter, number of branches leaf area and field survival. They also obtained fair differences between phenotypic and genotypic coefficient of variability. Heritability, broad sense values were fairly good with regard to leaf area, height and collar diameter in comparison to survival per cent. The relative performance of these sources was fairly consistent throughout the observation period

High heritability for seedling traits was also recorded in *Terminalia arjuna* by Srivastava et al (1993), In *Madhuca latifolia* (Jenner, 1995) observed that among the seedling parameters, shoot dry weight displayed high GCV, heritability and genetic advance as percentage of mean. The total dry weight possessed moderate heritability and genetic advances as percentage mean.

Among the 628 mulberry, *Morus* spp.) accessions, Indigenous-455; exotic-173) highest coefficient of variation was recorded for number of shoots, total shoot length, leaf yield and total biomass for exotics (Ananda et al., 2004; Gera et al., 2004) concluded that high values of heritability and genetic gain were observed for all the parameters studied in *Dalbergia sissoo viz.*, height, collar diameter, number of branches, indicating that these parameters were under strong genetic control.

Seed sources of *Pinus roxburghii* exhibited a wide range of variability in terms of mean values for various traits, standard deviation, variance, coefficient of variability, broad sense heritability, genetic advance and genetic gain and offer ample scope for undertaking screening for the desired traits (Roy et al., 2004).

The path co-efficient analysis, which apportions the correlation co-efficient in to direct and indirect effects and measure the relative importance of the casual factors involved (Dewey and Lu, 1959), may prove more useful. Though such analyses are common in annual crops, their use in tree crops is rather limited. In Simaruba Sekar (2003) reported that out of ten traits, six traits exercised positive direct effect on volume index. The highest positive direct effect on volume index was exerted by plant height, 6.374), collar diameter, 2.244) and leaf area index, 1.751), number of leaves expressed negative direct effect on volume index.

10 Studies on Seed Storability

Storage of seeds under ambient conditions was inevitable for seasonal sowing and under continuous production (Agrawal, 1995). The factors, such as moisture, temperature, gaseous exchange, seed coat characters, etc., determine the longevity of seeds under natural or controlled storage conditions (Barton, 1953). Seed treatment with pesticides is one of the pre-storage seed management practices that mitigate the deterioration rate of seeds under storage. In addition, the storability of seed is also influenced by the packing materials irrespective of its storage conditions (Copeland, 1988; Florido et al., 2002) suggested that the seeds may collect before the pods open. Extract the pods manually. Sundry seeds for 3 to 7 days to reduce moisture content up to 7%. Store in an air-tight container and keep in a cool place.

Seed treatments storage containers and storage periods

In storage, seeds treated with bavistin @ 2g/kg of seed and packed in 700 gauge polyethylene bags maintained 80% germination after 12 months storage, than the control which, cloth bag recorded only 70% (Nelsonnavamaniraj, 2005).

Srimathi, 1997) reported that Amla seeds stored better as seed treatment with Thiram + Sevin @ 2 g+2000 mg/kg of seed. In *Jatropha* (Kathiravan, 2004) reported that the storage studies expressed that the seeds treated with Bavistin + halogen mixture @ 1+1.5 g/kg, 1:1) of seed and packed in high density polyethylene inter woven bag, HDPE) or polylined cloth bag could be stored safely for 12 months with minimum loss in viability and vigour. To prolong the shelf life of Pungam seeds under ambient conditions (Jerlin, 1998) treated the seeds with halogens, Chlorine and Iodine @ 4 g/kg of seed both as dry and slurry treatments), neem leaf powder, 250 g/kg of seed) and thiram, 2 g/kg of seed) and stored in cloth bag and 300 gauge polylined cloth bags for six months. She reported that the viability of the seeds declined with increase in the periods of storage irrespective of containers and treatments and the decline was rapid in untreated seeds and in cloth bags. Iodination proved its superiority over other treatments in retaining higher viability for longer period. Among the containers, the seeds packed in polylined cloth bag maintained higher viability than the other containers irrespective of treatments.

Singh et al (1997) tested neem seeds under two methods of drying, after depulping the fruit) *viz.*, sun drying and shade drying. Moisture loss was more rapid during sun drying, dropping from an initial 26.6%~6.0% in six days, compared with 11% in shade dried seeds, They also reported that drying did not reduce germination much from sundried. Seed germination which was 84 per cent was maintained as high as 60% even at 6.0% moisture content. Storing seeds with high moisture content (>25 %) under deep freeze conditions had a deleterious effect on viability. Storage of such seeds under ambient or refrigerated conditions gave better results, but viability loss was less if seeds were stored under ambient or refrigerated conditions with a moisture content <10%, i.e. after drying, Ponnuswamy et al., 1991) stored seeds at an ambient temperature of 33.8°C and recorded a germination of 8.0 per cent at the end of three months compared with 90% when freshly collected. They attributed the loss to desiccation injury as the moisture content dropped from an initial 30.8% to a low level of 15.5% at the end of three months. In contrast, seeds stored in earthen pots burried in moist sand bed manifested little loss in seed moisture content and recorded a germination of 62% at the end of three months. Mohan et al (1995) evaluated the different wet storage methods, with the fresh ripe fruits of neem collected in Maharashtra, that were mechanically depulped, transferred to gunny bags for 5, 7 or 9 days of drying and then mixed with six storage media *viz.*, charcoal dust, lime powder, common salt, sand, black cotton soil and sawdust @500 seeds per 500 g of seed. The mixtures and control seeds without any storage media were kept in airtight plastic bottles at room temperature (28°C~35°C) for 13 weeks before sowing outside in raised beds. Germination in control seeds was found to be only 0~4% in all drying treatments, but all the storage media enhanced germination, and the best (32%~42%) was with black cotton soil, while charcoal dust the poorest, 12%~23%.

In Simaruba, Sekar (2004) reported that the seeds are orthodox in nature and could be stored well at low temperature for several years. He also reported that, the germination of fresh seed ranges from 70%~80% and it could be packed in paper/cloth bags and stored under room temperature for 9-12 months without loss in viability.

In Mahua, Singh and Saha (1994) collected samples from Bihar forests of India and stored the seeds in earthen pots, gunny bags and metal containers for 6 months. On evaluation of seed mycoflora they found that the seeds were contaminated with *Aspergillus flavus*, *A. niger*, *A. ochraceus*, *A. tamari* and *Penicllium purpurogenum* both initially and after storage but, in earthen pots and gunny bags the fungal contamination was at higher levels compared to sealed metal containers. In Mahua**,** Vanangamudi and Palanisamy (1989) revealed that storage of seeds in paper bags under ambient conditions, 28.5°C, 67% RH) resulted in complete loss of viability within 20 days. In Sal, *Shorea robusta*), Tempest (1985) collected seeds of *Shorea almon, S. robusta* and *S. roxburghii* from Malaysia, India and Thailand respectively and subjected them to different desiccation treatments and the results revealed that the germination declined when moisture content were reduced below 35% in *S. roxburghii,* below 40% in *S. almon* and *S. robusta*. Masano and Mawazin (1997) stored the seeds of sal in open and closed plastic bags with and without charcoal medium and found that storage of seeds in closed plastic bags was the best method as it maintained the germination as high as 92% after five weeks of storage. The presence of charcoal did not made any difference in germination while the storage in open plastic bags decreased the germination to 65%~75% after three weeks and to 45%~60% after five weeks. Bhargava et al (1999) harvested the matured seeds of *Shorea robusta* and exposed to the vapour of chlorine and iodine for different time periods and subsequently stored at 8°C, 15°C and room temperature. It was observed that treatment with chlorine vapour significantly enhanced the storability and tolerance to lower storage temperature. Exposure for 65 hour gave germination as high as 30% under nursery conditions, even after 15 days, while the untreated seeds failed to germinate. The results indicated the possibility of stabilization of the lipoprotein membranes of the cells, rendering them less susceptible to peroxidative changes during ageing. Chaitanya et al, 2000) revealed that a rapid loss of viability was recorded in sal seeds collected from Raipur, India when dehydrated below 36.7% moisture content, at ambient conditions. Seed became non-viable at six days after harvest. Bahuguna et al (1989) reported that *Mesua ferrea* could be stored at 5°C in perforated polythene bags upto two months without any deterioration from the initial germination potential and with 50% germination upto four months.

Krishnasamy (2005) reported rapid decrease in germination of Jack (*Atrocarpus hererophyllus*) seeds from 92% to 12% within 20 days of extraction. Drastic reduction in germination coincided with 44 per cent seed moisture content. The storage life of jack (*Atrocarpus heterophyllus*) seeds, recalcitrant) could be extended to nine months from harvest under ambient condition by incubating the fresh seeds with sand containing 10% Jalsakti or a 0.3 M solution of KH_2PO_4 and storing them in loosely bound polythene bags under ambient storage conditions of Calcutta (Bhattacharya et al., 1991). As the storage period advanced, reduction in germination percentage, root and shoot length, dry matter production and vigour index was reported by Vijayaraghavan (2000) in *Acacia nilotica* and *Albizia lebbeck*.

11 Conclusion

Based on the literature it can be concluded that the heartwood of the *Caesalpinia sappan* is widely used in traditional medicine and chemical investigation resulted in the isolation of novel and interesting phytochemicals possessing potent biological properties. Due to its vast and proven medicinal properties and use as dyeing agent, the wood has received both domestic and international market and being exported to USA and Europe from India, Philippines and from several other countries (Badami et al., 2004).

The importance of tree seed in tree research, education, and trees on farms for that matter, can hardly be better expressed than what one of the questionnaire respondents in this study expressed: "Tree seed is the mother of forestry". The most successful tree improvement programme is that where proper seed sources were used. The loss from using the wrong sources can be great and even disastrous (Zobel and Talbert, 1984; Schmidt, 2000) outlines the uniqueness of seeds in natural regeneration and propagation; seeds constitute unique genetic composition, resulting from mixing parental genetic material, leading to genetic variation of the offspring, which enhances ecological adaptability. Seeds are usually produced in large numbers and are readily available each year or at longer intervals. Seeds are usually small concentrated packages of plant-to-be, containing plant nutrients for the establishment of the plant and, except for recalcitrant seeds, usually much more resistant to damage and environmental stress than vegetative propagules.

Caesalpinia sappan is commonly propagated through seeds. When planting trees it is important to consider using seeds of trees with desirable characteristics. Various studies shows that seed provenances of trees from similar environment should also are considered when preparing a plan for planting trees (Conrad et al., 1995). The present review discusses the seed source variation and increase the seed longevity in suitable storage techniques. The wood *Caesalpinia sappan* has already proved export quality of natural dye and it has the potential to become a drug to enter into the world market due to its interesting biological effects and vast folklore uses is worth that might provide a rich natural resources. In future, more basic research is needed to elucidate the mechanism to appraise the better seed source variations and seed storage behaviuor and techniques in *Caesalpinia sappan.*

Reference

Agrawal R.L., 1995, Seed Technology, Oxford and IBH, Publishing Co. PVT. Ltd. New Delhi. pp.772

Allen O.N., and Allen E.K., 1981, In: The Leguminosae: A source book of characteristics, uses and nodulation. Madison WS. University of Wisconsin Press. pp.812

Ananda R.A., Tikader A., and Thangavelu K., 2004, Assessment of genetic diversity of growth and reproductive behaviour in Mulberry germplasm and utilization, Ind. J. For., 27(4): 372-380

Arthanari P., 2008, Studies on seed source variation and storage techniques in *Caesalpinia sappan* Linn. M.Sc. Thesis. Tamil Nadu Agricultural University, Coimbatore

Arya S., Toky O.P., Bisht R.P., Tomar R., and Harris P.J.C., 1992, Provenance and seedling growth of *Prosopis cineraria*, L.) Druce in arid India, Silvae Genetica, 41: 322-327

Badami S., Moorkoth S., and Suresh B., 2004, *Caesalpinia sappan:*a medicinal and dye yielding plant, Natural Products Radiance, 3(2): 75-82

Bahadur R., and Hooda M.S., 1995, Genetic variability and correction studies for some pod and seed traits in khejri *Prosopis cinerraria*, L.) Pruce, Ind. J. For., 18(2): 161-164

Bahuguna V.K., Unnikrishnan K.P., and Dhaudiyal U.C., 1989. Studies on the performance of Philippines and Malaysian provenance of *Albizia falcatoria*, L.) Febrez at nursery stage under north Indian tropical condition, Indian Forester, 115(4): 209-215

Barton L.V., 1953, Seed storage and viability, Boyce Thompson Inst, London, 87-103

Benazir J.A.F., Manimekalai V., Ravichandran P., Suganthi R., and Dinesh D.C., 2010, Properties of fibres/culm strands from mat sedge–cyperus pangorei Rottb, BioResources, 5(2): 951-967

Bhargava A., Marzalina M., Khoo K.C., Jayanthi N., Tsan F.Y., and Krishnapillay B., 1999, Use of halogens in enhancing storability of sal, Shorea robusta), Technical Bulletin, 13: 54-62

Bhat G.S., and Chauhan P.S., 2003, Seed source variation in seed and seedling traits of *Albezzia lebbek* Benth, J. Tree Science., 21(1-2): 52-57

Bhattacharya A.K., Lahiri A.K. and Basu R.N., 1991, Improvement of germination ability of Eucallyptus spp. by pre-germination treatments, Indian Forester, 117: 662- 663

Buchanan R., 1999, A Weaver's Garden: Growing Plants for Natural Dyes and Fibers. Dover Publications.inc., New York. pp.233

Chaitanya K.S.K., Keshavkant S., and Naithani S.C., 2000, Changes in total protein and protease activity in dehydrating recalcitrant sal, *Shorea robusta*) seeds, Silva Fennica, 34: 71-77

Chennagowda S., Farooqi A.A., Srinivasappa K.N., and Vasundrara M., 2001, Studies on pre- germination in natural dye yielding tree *Caesalpinia sappan* L., Ind. J. For., 24(3): 320-323

Chopra D., and Hooda M.S., 2001, Genetic variability and correlation studies in seed traits of mesquite, Prosopis juliflora, SW) DC.), Ind. J. For., 24(2): 162-165.

Conrad C.E, Fujii D.M., and Ikawa H., 1995, Seed source and performance in Koa tree establishment. Hawaii agriculture: Positioning of growth, April 5 and 6, 1995. University of Hawaii, Manoa, Honolulu, Hawaii. pp.88-89

Copeland L.O., 1988, Principles of Seed Science and Technology. Burgess Publishing Company Uinneapolis. pp.368

Dewey R.D., and Lu K.H., 1959. A correlation and path analysis components of crested wheat grass seed production. *Agron. Journal.* 51: 515-518 http://dx.doi.org/10.2134/agronj1959.00021962005100090002x

Divakara B.N., 2002, Clonal evaluation and genetic diversity studies using biometric and isozyme approaches in *Tamarindus indica* L. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Dwivedi A.P., 1993, National level neem province trail at Jodhpur. In: Proc. of the Intl. consultation of neem importance. Kasetsart University, Thailand. Pp.18-28

Fairey T.D., Loch D.S., Hampton J.G. and Ferguson, J.E., 1999, Forage Seed Production: Tropical and Subtropical Species. CAB International, UK. pp.479

Florido H.B., Priscilla B. de M., Pader L.P. and Cortiguerra F.F., 2002, Research information series on ecosystems, 14(1): 1-7

Furman, K.C., Woodstock, L.W. and Soloma, T., 1987, Interfacing - The ASAC- 1000 Seed analyser with an IBM-PC microcomputer using the basic Program- ASACSTAT. *J. Seed Technol.* 11(1): 79-87

Geethanjali K., Balasubramanian A., and Paramathma M., 2004, Seed technological studies in *Jatropha curcas*. In: Proceedings of the National Workshop on "Jatropha and other perennial oilseed species", August 5-8, 2003. BAIF Development Research Foundation, Pune, India, Eds. Hegde N.G, Daniel, J.N., Dhar, S, pp.31-33

Gera M., Gera ., Aggarwal R., and Gupta B.N., 2004, Seed source variation as observed under scanning electron microscope in leaf characters of *Dalbergia sissoo* Roxb, Indian Forester, 130(5): 498-512

Ghosh R.C., Singh B., and Sharma K.K., 1981, Suitability trials of different species and provenances of Pines in the Doon Valley of India, Indian Forester, 107(3): 135-150

Ginwal H.S., Gera M., and Gera M., 2000, Genetic variation in seed germination and growth performance of 12 Acacia nilotica provenances in India, J. Trop. Forest Sci., 12(2): 286-297

Ginwal H.S., Phartyal S.S., Rawat P.S., and Srivastava R.L., 2005, Seed source variation in morphology, germination and seedling growth of *Jatropha curcas* L. in Central India. *Silvae Genetica*. 54(2): 76-80

Ginwal H.S., Rawat P.S., and Srivastava R.L., 2004, Seed source variation in growth performance and oil yield of *Jatropha curcas* L. in Central India. *Silvae Genetica*. 53(4): 186-192

Halder S., and Gupta K., 1982, On the mechanism of sunflower seed deterioration under low and high relative humidity. *Seed Sci. and Technol*. 10: 267-270

Heydecker W., 1972, Vigour. In: Viability of seeds, Ed.) Roberts, E.H., Chapman and Hall, London. pp.209-252 http://dx.doi.org/10.1007/978-94-009-5685-8_8

Holmgren V., Savathvong S., Kvitvik T., Mattila K.M., Meyer G., and Redl T., 2003, Biodiversity Country Report. Ministry of Agriculture and Forestry, MAF) Science, Technology and Environment Agency, STEA), Vientiane, Lao. pp.169

Jansen P.C.M., 2005, Dyes and Tannins. PROTA Foundation, Netherland. pp.216

Jenner G.V., 1995, Studies on genetic analysis of seed and juvenile seedling attributes in Mahua, *Madhuca latifolia* Roxb., M.Sc. Thesis. Tamil Nadu Agricultural University, Coimbatore

Jerlin R., 1998, Seed technological studies on Pungam, *Pongamia pinnata* L. Pierre, Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Johnson H.W., Robinson H.F., and Comstock R.E., 1955. Estimation of genetic and environmental variability in soy bean, Agron. J., 47: 314-318 http://dx.doi.org/10.2134/agronj1955.00021962004700070009x

Kathiravan M., 2004, Seed production, processing, testing and storage techniques in Jatropha, *Jatropha curcas* Linn., Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Khatun B.M.R. and Rahman M.O., 2006, Taxonomic revision of the genus Caesalpinia l., Caesalpiniaceae) for Bangladesh, Bangladesh J. Plant Taxon, 13(2): 93-109

Kirtikar K.R., and Basu B.D., 1989, Indian medicinal plants, Blatter E., Caius JF and Mhaskar KS, Ed), Lalith Mohan Basu, Allahabad. pp.847 - 848

Kjaer E.D., and Foster G.S., 1996, The economics of tree improvement of teak. Technical Note No. 43. The World Bank and Danida forest seed centre, Denmark

Krishnan B.K. and Toky O.P., 1996, Seed source variation in seed characters of Acacia nilotica sub sp. indica, Benth.) in Arid India. *Indian Forester.* 121: 179-186

Krishnasamy V., Ponnuswamy A.S., Balamurugan P., Srimathi P., Natarajan N., and Raveendran T.S., 2005, Compendium on seed science and Technology. TNAU Offset Press, Directorate of Publication, Coimbatore

Kumar R., Toky O.P., and Chopra D., 2003, Seed source variation in tree and seed morphological characteristics of *Prosopis cineraria*, L) druce. *My Forest*. 39(2): 159-163

Kumar S., Parimallam R., Arjunan M.C., and Vijayachandran S.N., 2003b, Variation in *Jatropha curcas* seed characteristics and germination. In: Proceedings of the National Workshop on "Jatropha and other perennial oilseed species", August, 5-8, 2003. BAIF Development Research Foundation, Pune, India, Eds. Hegde, N.G, Daniel, J.N and Dhar, S, pp.63-65

Kumar S., Parimallam R., Arjunan M.C., and Vijayachandran S.N., 2004a, Effect of seeds size on germination and seedling growth of Jatropha curcas. In: Proceedings of the National Workshop on "Jatropha and other perennial oilseed species" In: Proceedings of the National Workshop on "Jatropha and other perennial oilseed species", August, 5-8, 2003. BAIF Development Research Foundation, Pune, India, Eds. Hegde, N.G, Daniel, J.N and Dhar, S, pp.55-59

Kumar S., Parimallam R., Arjunan M.C., and Vijayachandran S.N., 2004b, Variation in Jatropha curcas seed characteristics and germination. In: Proceedings of the National Workshop on "Jatropha and other perennial oilseed species" In: Proceedings of the National Workshop on "Jatropha and other perennial oilseed species", August, 5-8, 2003. BAIF Development Research Foundation, Pune, India, Eds. Hegde, N.G, Daniel, J.N and Dhar, S, pp.63-67

Kumar S., Parimallam R., Arjunan M.C., and Vijayachandran S.N., 2003c, Variation in seed parameters and bio chemical composition of *Pongamia pinnata*, L) Pierre in Tamil Nadu. In: proceedings: National Workshop on "Jatropha and other perennial oilseed species", August, 5-8, 2003. BAIF Development Research Foundation, Pune, India, Eds. Hegde, N.G, Daniel, J.N and Dhar, S, pp. 103 – 105

Kumar S., Parimallam R., Arjunan M.C., and Vijayachandran S.N., 2003a, Effect of seed size on germination and seedling growth of *Jatropha curcas*. In: proceedings: National Workshop on "Jatropha and other perennial oilseed species", August, 5-8, 2003. BAIF Development Research Foundation, Pune, India, Eds. Hegde, N.G, Daniel, J.N and Dhar, S, pp.55-57

Kurain A., and Sankar M.A., 2007, Medicinal plants. New India Publishing Agency, New Delhi. pp.363

Lacaze J.F., 1978, Advances in species and provenance selection. *Unasylva*. 30(119-120): 17-20

Lavania S.K. and Singh V., 2004, Effect of seed source on germination and early seedling growth in Himalayan Poplar, *Populus ciliata*) Wall. Ex Royale. *Ind. J. For.* 27(1): 15 -18

Mahadevan N.P., Sivakumar V., and Singh G.B., 1999, Relationship of cone and seed traits on progeny growth performance in *Caesurina equisetifolia* Forst, Silvae Genetica, 48(6): 273-277

Mani G., 2000, Studies on seed source variation in standardization of seed testing procedures and nursery technologies in Neem, *Azadirachta indica* A Juss, Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Manonmani V., 1997, Investigations on seed collection, storage and germination of teak, *Tectona grandis* L.) and, *Santalum album*, Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Masano and Mawazin, 1997, Storage of *Shorea selanica* seeds. Buletin Penelitian Hutan. pp.606: 1-8

Merritt D.J. and Dixon K.W., 2011, Restoration Seed Banks—A Matter of Scale. *Science.* 332: 424-425 http://dx.doi.org/10.1126/science.1203083

Mishra C.M., Dubey P., Burfal B.S., Banerjee A.C., and Singh S.L., 1997, Performance of *Azadirachta indica* provenance at seed and seedling stage. In: IUFRO Symposium on "Innovations in forest tree seed science and nursery technology", November 22-25, 1997, Pt. Ravishankar Shukla University, Raipur, India. pp.144

Mohan J., Chaudhari L.D., and Jha M., 1995, A note on increasing the viability of neem seed. Jalna, Maharashtra, India. Special issue: neem - gift of the gods, Indian Forester, 121(11): 1085-1086

Nelsonnavamaniraj K., 2005, Studies on phenology, seed collection and post-harvest seed management techniques for production of quality planting stock in *Bixa orellana*. Ph.D Thesis. Tamil Nadu Agricultural University, Coimbatore

Nkang A., Omokara D., and Egbe A., 2000. Effects of desiccation of the lipid peroxidation and activities of peroxidase and polyphenol oxidase in seeds of *Telfaria occidentalis*. *Seed Sci. & Technol.* 28: 1-9

Orwa C., Mutua A., Kindt R., Jamnadass R., and Anthony S., 2009, Agroforestree Database: a tree reference and selection guide version 4.0., http://www.worldagroforestry.org/sites/treedbs/treedatabases.asp

Paramathma M., Surendran C., and Rai R.S.V., 1997, Studies on heterosis in six *Eucalyptus* species. *J. Trop. For. Sci*. 9(3): 283-293

Parthiban K.T., 2001, Seed source variations, molecular characterization and clonal propagation in teak, *Tectona grandis* Linn f., Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Philomina D., 2000, Genetic analysis of one-parent families for variability, diversity, stability and propagation techniques in neem, *Azadirachta indica* A. Juss, Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Ponnuswamy A.S., Rai R.S.V., Surendran C., and Karivaradharaaju T.V., 1991, Studies on maintaining seed longevity and the effect of fruit grades in neem, *Azadirachta indica* Juss., J. Trop. For. Sci., 3(3): 285-290

Roecklein J.C., 1987, A Profile of Economic Plants. Transaction.inc., New Jersey. pp. 631

Roy S.M., Thapliyal R.C., and Phartyal S.S., 2004, Seed source variation in cone, seed and seedling characteristic across the natural distribution of Himalayan low level pine, *Pinus roxburghii* sarg, *Silvae Genetica*. 53(3): 116-123

Schmidt L., 2000, Guide to handling of tropical and subtropical forest seed. DANIDA Forest Seed Centre, Humlabaek, Denmark. 511

Sekar I., 2003, Seed storage, seed source variations, molecular characterization and in vitro propagation in *Simarouba glauca* DC. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Sekar I., 2004, Silviculture of *Simarouba glauca* DC. In: ICAR winter school – short course on Strategies for improvement and utilization of tree borne oil seeds., Ed.) Paramathma, M., Parthiban, K.T. and Neelakantan, K.S. Forest College and Research Institute, Tamil Nadu Agricultural University, Mettupalayam

Senthilkumar N., Murugesan S., Banu N., Supriya S. and Rajeshkannan C., 2011, Biochemical Estimation and Antimicrobial Activities of the Extracts of *Caesalpinia Sappan* Linn. Bangladesh Journal of Scientific and Industrial Research, 46(4): 429-436

Shahid M., and Mohammad F., 2013, Recent advancements in natural dye applications: a review. Journal of Cleaner Production. 53(15): 310–331 http://dx.doi.org/10.1016/j.jclepro.2013.03.031

Sindhu V.H.C., 1995, Variation studies in provenances of *Azadirachta indica*, Indian Forester, 11: 1053-1056

Sindhuveerendra H.C., Ramaalakshmi S., and Mallesha B.B., 1999, Variation in seed characteristics in provenances of sandal, *Santalum album* L., Indian Forester, 125(3): 308-312

Singh B.G., Mahadevan N.P., Shanthi K., Manimuthu L., and Geetha S., 1997, Effect of moisture content on the viability and storability of *Azadirachta indica* A. Juss, neem) seeds, Indian Forester, 123(3): 631-636

Singh B.K., and Saha N.K., 1994, Impact of storage systems on mycoflora of *Madhuca longifolia* seeds, Indian Phytopath, 47: 266-269

Siva R., 2007, Status of natural dyes and dye yielding plants in India. *Current Science*. 92(7): 916-925

Sivasamy M., 1991, Net production effect, seed production spectrum and quality polymorphism as influenced by ecology in *Azadirachta indica* A. Juss., *Derris indica* L. and *Ailanthus excelsa* Roxb. seeds. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Smartt J., 1990, Grain Legumes: Evolution and Genetic Resources. Cambridge, New York. p.381

Solanki K.R., Muthana K.D., Jindal S.K., and Arora G.D. 1984. Variability, heritability and correlation for growth parameter in *Prosopis cineraria*, J. Tree Sci., 3(1&2): 86-88

Srimathi P., 1997, Research focus on seed collection, processing and storage of Amla, *Emblica offinalis*), Jamun, *Syzygium cuminii*) and Ber, *Zizyphus mauritiana*, Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Srivastava D.P., Srivastava P.K., Goel A.K., and Thangavelu K., 1993, Genetic variability in *Terminalia arjuna*, Ind. J. Forestry, 16: 223-225

Surendran C., Rai R.S.V., Sivagnanam K., Shanmugam M., Kumaran K., Ragupathi A., Vanangamudi K., and Vimala I., 1993, Tree improvement and seed management in Indian neem. In: Genetic improvement of neem. Strategies for the future. Proc. Intl. Consultation on neem improvement held at Kasetsart University, Bangkok, Thailand. Pp.29-39

Talavero V.P., and Apitong N.B., 1992, Sibukao: A potential fuel wood species. Techno Transfer Series. DENR-ERDB Reg. 6. 3

Tempest P.B., 1985, The influence of moisture content and storage temperature on the viability of Shorea almon, Shorea robusta and Shorea roxburghii seed. Can. J. For. Res. 15(6): 1074-1079 http://dx.doi.org/10.1139/x85-175

Troup R.S., 1921, Silviculture of Indian trees. Oxford University Press, London. pp.79

Tyagi P.C., Agarwal M.C., and Kumar N., 1999, Provenance variation in seed parameters and germination of Grewia optiva Drummond, Indian Forester, 5: 517-521

Umarani R., 1999, Studies on the physiological and biochemical basis of seed germination and deterioration in *Casuarina equisetifolia*. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Umarani R., Bharathi A., and Karivaratharaju T.V., 1997, Effect of provenance on seed storage of *Casuarina equisetifolia*, J. Tree Sci., 16(1): 20-23

Umeshkanna S., 2001, Genetic analysis, biochemical and molecular characterization of *Madhuca latifolia* Macb. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Vakshasya R.K., Rajora O.P., and Rawat M.S., 1992, Seed and seedling traits of *Dalbergia sissoo* Roxb. seed source variation studies among ten sources in India, For. Eco. Manage, 48: 265-275

Vanangamudi K., and Palanisamy V., 1989, Viability of illupai, *Madhuca longifolia* var. *latifolia*) seed, Seed Res., 17(2): 186-187

Vanangamudi K., Umarani R., Bharathi A. and Venkatesh A., 1998, Effect of seed source on physical and physiological qualities of Acacia nilotica seeds, Seed Res., 26(2): 114-116

Venkatesh A., 2000, Studies on seed source variations, standardization of seed testing procedures and nursery techniques in (*Acacia nilotica* L.) Wild Subsp indica benth. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore

Vijayaraghavan A., 2000, Physiological and Biochemical changes during seed deterioration in (*Acacia nilotica*, L.) Willd. Subsp. indica Benth. and (*Albizia lebbeck* L.) Benth. M.Sc. Thesis. Tamil Nadu Agricultural University, Coimbatore

Warriers P.K., Nambiar V.P.K., Ramankutty C., and Varriers V.P.S., 1993, Indian Medicinal Plants, A compendium of 500 species, Orient Longman Ltd., Chennai. 1: 291-294

Woodstock L.W., and Feelay J., 1965, Early seedling growth and initial respiration rates as potential indicator of seed vigour in corn. Proc. Ass. Off. Seed Anal., 66: 131-139

Zobel B.J., 1971, The genetic improvement of southern pines. Sci. Amer., 225: 94-103 http://dx.doi.org/10.1038/scientificamerican1171-94

Zobel B.J., and Talbert J., 1984, Applied tree improvement. John Wiley & Co., New York. pp. 503