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Research on *Anogeissus pendula* in India: A Review

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Abstract

Due to high pressure of animals and human, the grazing lands and forest land are deteriorating and are not able to supply adequate green, dry forages to livestock and timber, fuelwood for human in India. To overcome this problem, introduction of *Anogeissus pendula* is one of the alternative which is naturally found in dry tropical forest and dry mixed deciduous forest of Rajasthan, parts of Gujrat, Maharashtra, Madhya Pradesh, Haryana and Bundelkhand region of Uttar Pradesh. In the present paper, efforts have been made to review the various aspects such as seed germination, vegetative propagation, establishment, growth, biomass production, insects and pests, nutritive value, performance in agroforestry systems, soil improvement *etc*. of the species. Available information indicate that *A. pendula* is suitable tree species with a wide range of adaptability and can be introduced in different systems of agroforestry specially silvopastoral system in rocky-gravelly land for enhancing the total biomass production and soil improvement.

Key words : Agrisilviculture system, *Anogeissus pendula,* Calorific value, Conservation, Peninsular, Phenology, Silvipasture.

Introduction

A*nogeissus pendula* (family Combretaceae) is commonly known as *Dhaunkra*, *Dhav*, *Kala Dhaura* in Rajasthan and Uttar Pradesh (Bundelkhand region), *Dhau*, *Dhaunkra* in Gujarat and Kardhai in Maharashtra. It is a small, gregarious, drought resistant, dry deciduous tree having light spreading crown and strong roots. It is found growing naturally in whole of the Aravalli hills in India and even in crevices of the rocks in these hills. Five species of *Anogeissus* reported from India are : *A. acuminata* (Roxb.) Wall. ex Guill. and Perr., *A. latifolia* (Roxb.) Wall. ex Bedd.*, A. pendula* Edgew*, A. rotundifolia* and *A. sericea* Brandis. Out of these species *A. acuminata, A. latifolia and A. pendula* yield valuable timber (Chadha, 1985) . The fossil records of *Anogeissus* are quite astonishing. The Mio-Pliocene epoch of the Tertiary period of the Cenozoic era in Cuddalore-series and the Tertiary rocks of Pondicherry (south India), exhibit a luxuriant growth of *Anogeissus*. A form of the genus *Anogeissusxylon*- very similar to *Anogeissus,* has also been recorded from the vicinity of Pondicherry. Fossil wood resembling *A. acuminata* has been collected and recorded from Algeria. This clearly indicates the cosmopolitan distribution of *Anogeissus* during Ut Supra Geological time (Navale, 1962). *A. pendula* has showed a very good fire, tolerant capacity grown in red gravelly and medium black soil (Rai and Singh, 1996). The leaves of tree are palatable and contain 13.61% crude protein on dry weight basis (Rai *et al*., 1995). Looking to the importance and multiple uses of this species an effort have been made to review the information on different aspects such as seeds and its germination, vegetative propagation, establishment, growth, biomass production, insects and pests, nutritive value, performance in agroforestry system, soil improvement *etc*.

Distribution

A. pendula is distributed throughout the tropical Asia and Africa. In India, the species commonly occurs in dry tropical forests and dry mixed deciduous forests of Rajasthan, parts of Gujarat, Maharastra, Madhya Pradesh, Haryana and Bundelkhand region of Uttar Pradesh. *A. pendula* is the predominant tree of Aravalli hills of Rajasthan and of Sabarkantha and Banaskantha divisions of Gujarat, where it forms pure forests. Further, it is distributed northward to Jhansi, Hamirpur and Banda district of Bundelkhand region of Uttar Pradesh as also southwards to the river Narmada in Nimar district of Madhya Pradesh. It is very common in Tikamgarh, Datia, Chattarpur, Gwalior and Shivpuri forests and abundant in many parts of Rajasthan, especially in Ajmer-Marwar forests.

Singh *et al*. (1983) reported that *A. pendula* appears to occur on sites relatively much poor in C/N ratio (10 or less) than that for *A. latifolia*. Both these species are

found on soils having 6.3 to 6.5, pH. In Bundelkhand area of U.P., *A. pendula* grows on quartzite ridges in association with *Diospyros melanoxylon, Acacia catechu, Zizyphus xylopyrus, Bauhinia racemosa, Odena wodier* and *Butea monosperma* (Singh, 1982). In Bundelkhand region, it grows naturally in crevices of rocks wherein the parent rock is mainly gneiss giving rise to a thin layer of coarse gravely red soils. *A. pendula* grows well on soils with a pH range of 5.5- 7.0, silt plus clay proportion of 10- 30%, base exchange capacity of 2.2- 10.4 meq/ 100gm, organic matter of 1.7 % and available phosphorus level around 140- 180 kg/ha, K_2O of 220- 300 kg/ha and total nitrogen of about 0.003- 0.004 % (Gupta, 1967).

Verma (1972a) has described dry deciduous forests of Rajasthan where pure stands of *A. pendula* are common; elsewhere *A. pendula* grows in association with *Acacia catechu, Acacia leucophloea, Wrightia tinctoria, Bauhinia racemosa, Diospyros melonoxylon, Flaocourtia ramontchii* and *Dichrostachys cinerea.*

Mathur and Bhatnagar (1992) reported that *A. pendula* was the major species alongwith *Parkinsonia aculeata, Prosopis cineraria, Ziziphus nummularia, Acacia tortilis, Dichrostachys cinerea, Adathoda vasica, Prosopis juliflora, Acacia nilotica, Holoptelia integrifolia* in Ambagarh forest division of Jaipur (Rajasthan)

A preliminary ecological survey of Algual spring, Sariska Tiger Reserve of Rajasthan revealed that hills side vegetation was dominated by *Boswellia serrata* woodland upto 13 m tall with a lower layer of *A. pendula* and some *A. catechu*, *B. racemosa, W. tinctoria* (Rodgers, 1990).

In the old growth stands of *A. pendula* at Alwar and Sawai Madhopur, humus layers were seldom built to a depth of more than 5 cm beneath which was a Grey leached layer of sandy soil 7-14 cm thick overlying a brownish layer of sandy soil a few meter thick in cracks and crevices of hill (Bhargava, 1951). Oven dried weight of forest litter of *A. pendula* in a 12 months period averaged 8700- 12000 kg/ha in a stand of 30- 35 years age; the composition of the same was CaO 2.12- 2.30%, MgO 0.43- 044%, K_2O 0.33- 0.36%, P_2O_5 0.16 -0.19%, SiO_2 0.79- 0.86%, Silica 5.91-6.61% and ash content 14.62- 15.50% on dry matter basis (Gupta, 1993).

The best growth of *A. pendula* on the Aravalli hills of Rajasthan was found on metamorphic and sub-metamorphic rocks, chiefly gneiss, schist, slate and quartzite with occasional lime stone and trap. In the Vindhyan range , it grows on sub- metamorphic rocks and sand stone . Moreover, it is reported that *A. pendula* obtained good growth where the soil was deep and underlying rock was gneiss or schist (Bhargava, 1951).

Analysis of vegetation at Datia (M.P.) revealed that pure forest of *A. pendula* (IVI 205.9) supports the minimum number of species as associate. This could be attributed to the dense overhead canopy of this species. At partially disturbed sites, *A. pendula* forest (IVI 74.34) have *B. monosperma* was widely associated species alongwith several other species. Moisture availability (through seasonal flow of water in nala) resulted in the occurrence of large number of species (12). *Phoenix sylvestris* was the dominant species (IVI, 91.4) followed by *H. integrifolia*, *A. pendula* etc. (Anonymous, 1995).

Ecological studies of Kolras forests range of M.P. revealed seven communities in the forests. The main species involved were *A. pendula, Boswellia serrata, Acacia catechu, Diospyros melanoxylon etc.* (Verma and Das, 1979). Survey of Madhav National Park at Shivpuri (M.P.) revealed that *A. pendula* was a major tree species alongwith *B. serrata, B. monosperma, A. catechu* (Ravan *et al.*, 1995).

A study in dry deciduous forest in the Bundelkhand region showed that 23 species comprise the study area out of which the 2 most common and dominating species were *Anogeissus pendula* [*A. acuminata*] and *Tectona grandis* (Anand *et al.*, 2001).

General characteristics

Botany

The tree is reported to have a maximum height of 12 m and girth of 1.5 m (Hocking, 1993). The bole of tree is generally crooked and short (3 m). The bark is smooth, grayish - brown to silvery white and fissured when old. Branches are pendulous or drooping. The leaves are small (2-5 x 1-2 cm) ovate and green. In the winter season, the leaves are silvery - white and shining. Flowers are whitish and in small heads of 0.5-1 cm diameter. Fruits are small (5 x 6 mm), orbicular, yellow brown, beaked and winged. At seedlings stage, the primary root is long, thin, terete and wiry. The lateral roots are short in number and length, fibrous and distributed down to the main root. Hypocotyle is distinct from root, 1.25 - 1.50 cm long, terete, minutely tomentose. Stem is erect, terete, wiry tomentose and with internodes upto 1.25 cm long. Leaves are simple, first pair usually opposite or sub opposite, subsequent leaves alternate, exstipulate. Cotyledon's petiole less than 1.25 cm long. Lamina is 0.50 - 2.5 cm by 0.25 - 1.25 cm, ovate, acute or acuminate, mucronate, entire, glabrescent above, pubescent on vein beneath and glandotted (Singh 1982).

Phenology

In the winter season, the leaves turn reddish brown and leaf fall commences in December with decrease in temperature. The trees become leafless in March and new foliage appears during May to June. During leaf-less period, even light rain showers induce new leaves. Flowering takes place towards the end of the rainy season in September. Fruits ripen from December to February and fall during March to April.

Wood quality and uses

A. pendula has multiple uses. Its timber is very hard, tough, strong, durable and is equivalent to teak in terms of transverse strength. It does not decay and discolour. Its timber has great potential value because of its strength and working qualities. It is used as poles and rafters in construction, for pickers arms, shuttles and bobbins, cart axles, shafts, wheel spokes and frames and in furniture making. They are also used as fuel or for making charcoal. The wood is of moderately good fuel efficiency. Hocking (1993) has identified it as an excellent fire wood (5300 k. cal/kg) and it is sold at premium prices in the market as compared to other fuel wood tree species. The calorific value of the sapwood is 4.837 kilo calories and that of the heartwood 4.739 kilo calories. Heartwood is blackish purple, heavy (946 kg/m^3), hard, difficult to saw, shock resistant and makes the best tool handles (Hocking, 1993). The weight, crushing strength, stiffness, retention of shape, hardness, shearness strength of teak (*Tectona grandis*) were 0.683 g/cm^3, 468 g/cm^2, 80.2 t/cm^2, 702.33 kg/cm^2, 527 kg, 91.89 kg/cm^2, respectively as reported by Troup (1986 b). When these parameters compared with *A. pendula* it was found to be ; 124-141, 103-112, 85-88, 64-70, 151-169, 136-151 %, respectively (Troup, 1986 a). The tree yields the Ghatti or Indian Gum which is edible and has medicinal value. The leaf yields a dye producing a dark green colour. The tree also gives tannins. The seed possess haemagglutinating property against the human A, B and O red cells Leaves are considered to be excellent fodder (Ganguli *et al*, 1964, Rai *et al*, 2007).

Seed and its germination

On an average, about 2 - 6 kg seeds per plant are obtained from 20 - 26 years old tree. Only about 40% fruits produce viable seeds. Average number of viable seeds per normal fruit is 6 - 10. Fruits produced in the upper one- third crown produce better seeds than those at lower levels. Seeds borne above the middle of fruits have higher viability than those in the middle or close to the base (Mathur, 1956).

Yadav and Tripathi (1983) reported morphological differences in the seed of *A. pendula* and *A. latifolia*. Seeds of both species are winged with a terminating beak but in the former the length of beak is equal/or larger than the seed length, whereas in the latter, it is half - to one -fourth of the seed length. Wings are homogeneous throughout the seed in *A. latifolia* whereas larger and well developed only on the lower half compared to the upper half in *A. pendula*. *A. pendula* had small and light seeds which were easily dispersed (Athya, 1985).

Aggregate average weight of *A. pendula* seed was 6 mg. ranging from 1 to 17 mg. This variation may be ascribed to the differences in moisture content and the proportion of seed filling in the form of stored reserve food materials and the embryo itself and inherent genetic differences, Number of seeds per gram ranged between 100 - 275 depending upon their individual weight. The seeds of *A. pendula* varied greatly in collections from different forest areas of the Bundelkhand region. The variation ranged from 4.66-7.00 mm, 3.28- 5.68 mm and 1.06- 2.06 mm for length, width and thickness, respectively (Saxena, 1989).

The fresh seeds of *A. pendula* contained average 13.4% of moisture by weight which ranged from 9% to 19 % depending upon the level of seed maturity. Seeds generally imbibe nearly equal amount of water by weight to become fully turgid in order to initiate the process of germination. This was observed after 48 hours of continuous soaking of seed at room temperature (Saxena, 1989). In biochemical staining the seeds, on an average, exhibited 15% viability. Production of unfertile seeds seems to be a major factor, which could be responsible for the poor germination percentage in *A. pendula*. Unfertile seeds may have been produced due to excessive seed abortion or failure of fertilization. Both, climatic and biotic factors play equally important role in the developmental process of *A. pendula* seeds (Saxena, 1989).

Saxena (1989) made following recommendation for higher germination of *A. pendula* seeds :

- For higher germination (average 10.6 %), seeds should be soaked for 24 hours at 35°C.
- To enhance the germination of seed, leachate of leaf litter of *A. pendula* should be prepared in the ratio of 1:100. From this leachate 1 % solution should be taken to get 14.29 % higher germination.
- It was observed that 60 minutes treatments at 50°C gave 10.2 % higher germination as compared to the control (8.2 %).

- The medium size (24- 43 mm^2) and heavy weight (more than 0.12 g) seeds showed 34.2 % higher germination compared to large size and heavy weight seeds or small size and heavy weight seeds.
- Seed soaking for 48 hours continuously of hormone Indole Acetic Acid (IAA), Indole Butyric Acid (IBA), Indole Propionic Acid (IPA), Naphthalene Acetic Acid (NAA). The IBA with 1000 ppm gave 92.5 % increase in germination followed by IBA of 500 ppm concentration.

Propagation technique

Natural

Study on the natural regeneration of A.pendula dominated forest area at Datia, Madhya Pradesh. revealed that all the species increased in number ranging from 443 to 1075 % after 5 years (Anonymous 1994-95). Similarily, Pandey and Singh, (1999) reported effective regeneration of *A. pendula* degraded forest after protection in the aravalli hills of Pali and Udaipur district of Rajasthan.

Vegetative

Since, the germination of A. pendula is very low (2 - 9 %), their establishment through vegetative propagation techniques has a great importance (Bhargava, 1951).

Vegetative propagation of *A. pendula* through stem cuttings and air layering is possible with the help of IBA solution of different concentrations (50 - 1200 ppm) in the rainy and spring seasons under normal nursery conditions. Spring season was best suited for rooting of stem cuttings as well as air layering in comparison to rainy season under normal nursery conditions. IBA treatments of 300 and 400 ppm for 24 hours for stem cuttings (40 % rooting) and 800 ppm for air layering (40 % rooting) were very effective for mass multiplication of *A. pendula* (Anonymous, 1998-99). In air layering technique, secondary/tertiary branches of 0.5 - 1.0 cm diameter from young trees are selected during rainy season. About 2.0 - 2.5 cm length of bark is scalped out cylindrically from 10 - 15 cm above the base of the branch. Then 800 ppm IBA solution through absorbent cotton moist with IBA solution is applied on the cut portion. The treated area is covered with a bit of moss moistened with water and tied with plastic ribbon. The rooted branches on the mother plant are detached after about 60 days and transplanted in polybags filled with sand and soil (1:1). The air layering is useful for producing a large sized plant in a short time.

Cotyledon and epicotyledonary nodal explants from four week old seedlings of *A. pendula* produced 15 to 20 and 4 to 5 shoots, respectively on MS medium containing 1 mg Benzyleadenine and 1 mg IAA/litre. Cotyledonary nodal segments were repeatedly sub-cultured to produce multiple shoot. Each explant produces 3 - 4 shoots. Which were rooted on half strength MS medium containing 1.5 mg IBA and 0.1 mg kinetin/litre. Approximately 800 plantlets were developed in about 200 days using this method. After hardening and acclimatization, plantlets were potted and 30 % survival was recorded (Joshi *et al*., 1991).

Seeds cultured on plant growth regulator-free, semi-solid Murashige and Skoog (MS) medium germinated within 5-6 weeks and formed 4-6 cm long shoots. The shoots multiplied on MS + 4.4 µM benzyladenine (BA) + 5.7 µM indoleacetic acid [IAA] + casein hydrolysate (100 mg/litre) + ascorbic acid (50 mg/litre) + sucrose (3%) + agar (0.8%). A majority of the genotype rooted with more than 90% efficiency when 5-6 cm individual shoots were cultured on 1/2MS (only major salts reduced to half strength) + 2.3 µM IAA + 2.5 µM indolebutyric acid [IBA] + sucrose (3%) + agar (0.8%) for 15 days. Those 10% genotypes that did not root well on the above medium could be rooted with ease by increasing the concentration of IAA in the rooting media from 2.3 to 5.7 µM. The in vitro-raised plants were successfully transferred to the soil with a success rate of over 85%. Using this protocol, over 560000 tissue-cultured plants of this species has been produced and dispatched to various state forest departments for field trials and routine plantations (Sexena and Dhawan, 2001).

Establishment, growth and biomass production

A. pendula is established through seeds, seedlings, stem cuttings, air layering and stump planting. Two year old seedlings were found better for establishment as compared to one year old seedlings (Mathur, 1961). Better seedlings establishment in black soil (2.6%) was reborted at IGFRI Jhansi as compared to red soils (1.0%) (Anonymous, 1985).

Maximum survival (3.9%) at the bottom of hillocks, whereas none of the seedlings survived at the top of hillocks in the natural forest of Sagar district of M.P. (Tripathi *et al.* 1986).

Out of three irrigation regimes, better growth in terms of shoot dry weight was found in altrernate days irrigation (0.055 g) followed by daily irrigation (0.040 g). The minimum growth of seedling was observed when irrigation was given twice a week (0.033 g) (Tripathi and Saxena, 1986).

Annual increment rate showed an increase of 0.19 m in height and 0.73 cm in girth in case of tended plants

(pruning up to 1.83m) against 0.11 m and 0.55 cm increase in height and girth under untended plants (Anonymous, 1994-95).

Troup (1986 b) suggested that to get clear bole pruning at least up to 50% height should be done eighter every year or alternate years. Otherwise plants may become a shrub.

Studies on evaluation of 14 multipurpose tree species (MPTs) under natural grassland having red gravely soils revealed that *A. pendula* showed very good survival (87.5%) at five years of age as compared to most MPTs like *Melia azadarach*, *Albizia procera*, *Acacia nilotica*, *Hardwickia binata*, *Eucalyptus tereticornis* and *Azadirachta indica* etc . However, it was noted by Rai *et al* (1995) that the growth (height 1.6m , cd 3.7 cm, dbh 1.17cm) and biomass production of 1.87 kg/tree (0.25 kg main bole + 1.47 kg branches + 0.15 kg leaves) was lowest among all the other MPTs.

Evaluation of 10 multipurpose tree species under rangeland condition in medium black soils revealed that the growth in terms of height (2.7 m), CD (4.2 cm), dbh (3.3 cm) and biomass production of 5.6 kg/tree (3.7 kg bole +1.5 kg branches +0.4 kg leaves) was minimum with *A. pendula* at eight years of age as compared to other nine multipurpose tree species. The mean annual increment (MAI) for height (0.34 m), CD (0.52 cm) and dbh (0.41 cm) was lowest in case of *A. pendula* (Rai, 1999).

Mathur (1956) reported that the growth of *A. pendula* is slow upto 10-15 years (2.7 m) due to die -back. Later on, it is fairly fast and it slows down again by 30-35 years. At 50 years the tree attains a height of 9 m and diameter of a 14 cm.

Insects and pests

Aphids, jassids, cutworms and spiders attack *A. pendula* from the very beginning, while grubs cut the root and inflict mortality. *Olenocamptus anogeissi* larva prevents plant growth. Ant climbs the tree when it is in flower. Termite attack is seen in green and dead. Borer damage is confined to upper parts of dying trees; the lower portion of the stem (0.5 m above ground level) is not generally attacked. Verma (1972b) reported two species of longicorn borer, namely, *Olenecamptus anogeisii* Gardener and *O. indianus* Thompson which attack the dead and dying trees and bore tunnel through sap wood and sometimes through heartwood also. Some plants were damaged by Bandha (*Dendrophtoe falcata)* which is one of the most common loranthaceous parasite. Spray of 2,4- D (0.75% solution) is reported to kill the parasite (Seth, 1958). The larvae of *Gelasma goniaria* Felder, *Urapteryx picticaudata* Walter and *Anua triphaenoids* Walter defoliate the trees (Bhasin and Roonwal, 1954).

Studies on vesicular arbuscular mycorrhizae (VAM) in *Anogeissus* species at the farm of NRCAF Jhansi revealed 100 % colonization of VAM presence. However, range of colonization index varied from 35.0 - 82.5 and 11.3 -78.8 in *A. latifolia* and *A. pendula*, respectively (Anonymous, 1998-99).

Association in agroforestry system

Evaluation of five genotypes (AP-12, AP-28, AP-35, AP-52 and AP-S_2) of A. *pendula* (seedlings raised through tissue culture at Tata Energy Research Institute, New Delhi) at NRCAF, Jhansi with two types of pruning management (pruning up to 25% and 50% height from ground level) under agri-silvicultural system revealed that average maximum growth in height (3.55 m), dbh (2.90 cm) and canopy diameter (3.30 m) were recorded in case of AP-28 and the minimum growth in height (3.09 m), dbh (2.15 cm) in AP-12 and canopy diameter (1.92 m) AP-52 genotype during 63 months of establishment. The maximum total pruned dry biomass production (2.42 t/ ha) was obtained by AP-28 followed by AP-S2 and AP-35 (Rai et al., 2002 a). Therefore, AP-28 genotype, seem to be very fast growing with capability to produce higher biomass, hence suitable for growing on degraded lands for higher leaf fodder and fuel wood production.

The pruning management studies for three MPTs namely, *H. binata*, *A. pendula* and *A. latifolia* were initiated from 1997-98 in the trees planted during 1989. There are four pruning treatments 10, 25, 50 and 75 % pruning. Blackgram was taken as intercrop during kharif season. The data recorded for tree growth parameter revealed that the pruning exhibited clear trend for tree growth parameters in *H. binata* (minimum height 7.85 m at 10 % and maximum 8.47 m at 75 % pruning) and *A. pendula* (4.74 m at 10% and 5.45 m at 75% pruning), whereas there was no clear trend for *A. latifolia* . The average maximum height (8.12 m) and DBH (18.01 cm) were recorded for *H. binata*, whereas, minimum height (5.13 m) and diameter (6.64 cm) were recorded for *A. pendula* (Table 1). The crop data presented in table 2 revealed that for *H. binata* the maximum values for plant population, no of pods, no of grain per pod and seed weight were recorded with 75 % pruning treatment. There was no clear trend for crop parameters for *A. pendula* and *A. latifolia*. The photosynthetically active radiation (PAR) differed significantly in all the treatments and maximum value were

recorded for 75 % pruning treatment and minimum with 10 % pruning treatment in all the three species. The pruning intensity has no significant role on the taper of the trees as trees were already well established and pruning initiated for the first time in 8 years old trees. The relation between pruning by height and crown volume removed revealed that maximum crown was removed with 75 % pruning intensity and at 10 % pruning crown volume removal was 0.0 %. At 75 % pruning intensity crown volume removed was 48.56, 54.69 and 49.57 % for *H. binata*, *A. pendula* and *A. latifolia*, respectively (Anonymous, 2001-02). Rai (2001) observed that pruning up to 50 % height of *A. pendula* produced 112.4 and 87.64 % higher total green and dry biomass production over pruning up to 25 % height of the tree, respectively.

Studies on *Anogeissus latifolia* and *A. pendula* based silvopastoral system in which pruning was introduced from 4, 5 and 6th year of plantation with 3 pruning intensities (25, 50 and 75% of height) and 2 control (unpruned trees with pasture and pasture without tree) for 5 years revealed that there was no significant effect of pruning treatments of growth parameters in both the species (Rai *et al.* 2006, 2007). However, in case of A. latifolia mean annual increment (MAI) at 7.5 years age ranged from 0.72-0.80 m for height and 0.79-0.9 cm for dbh. The dry leaf fodder and fuel wood production increased as the pruning intensities increased from 25 to 50 and 50 to 75% pruning height in both the tree species. On an average, maximum leaf fodder (398 kg/ha) and fuel wood (1612 kg/ha) was obtained at 75% pruning height when pruning initiated from 5th year onwards in case of *A. latifolia* (Rai *et al.,* 2006). In case of *A. pendula* maximum dry biomass of 1339.8 kg/ha (123.2 dry leaf fodder + 1216.6 kg fuel wood) was obtained when pruning initiated from 4th years onwards at 75% pruning height followed by 5th years (1268.0 kg/ha) and 6th years (1112.0 kg/ha) (Rai et al. 2007). Further it was observed that growth and biomass production under silvipatoral system in *A. latifolia* was about one and half times higher than *A. pendula* grown in similar situation.

Nutritive value and digetibility of leaves

Nutritive value studies of leaves showed that irrespective of the genotypes on an average, the Acid Detergent Fibre (ADF), Neutral Detergent Fibre (NDF), Crude protein (CP), condensed tannin (CT), lignin, ash, total phenol, *in-vitro* dry matter digestibility were 33.42%, 53.13%, 9.24%, 6.67%, 16.27%, 1.38%, 10.62% and 44.44% respectively (Rai *et al.,* 2002 b). Similarly Ganguli *et al.* (1964) reported the constituents of *A. pendula* leaves like CP (7.60%), crude fiber (19%), N free extract (65.30%), ash (8.10%) phosphorus (0.10%). Calcium (3.50%) and magnesium (0.30%). The nutritive value of *A. pendula* leaves observed by Ramana *et al.* (2000) were organic matter (945.8 g kg^{-1} DM), NDF (291.3 g kg^{-1} DM), ADF(192.9 g kg^{-1} DM), cellulose (65.4 g kg^{-1} DM), hemicellulose (98.4 g kg^{-1} DM), lignin (63.0 g kg^{-1} DM), total phenolies (73.2 g kg^{-1} DM), condensed tannin (19.9 g kg^{-1} DM). Rai *et al.* (2007) reported the *in-sacco* degradability of *A. pendula* leaves. The degradability of different constituents were 89.08, 88.54, 91.98, 70.62, 66.24 and 77.27% for dry matter, organic matter, crude protein, NDF, ADF and hemicelluloses, respectively. The higher degradability and organic matter represented the better quality as animal feed.

Table 1 : Effect of prunings on tree growth parameters of MPTs

MPTs	Pruning (%)	Tree height (m)	dbh (cm)
H. binata	10	7.85	18.12
	25	8.00	17.53
	50	8.42	18.42
	75	8.47	17.97
A. pendula	10	4.74	5.26
	25	5.00	6.09
	50	5.31	7.49
	75	5.45	7.79
A. *latifolia*	10	5.31	8.18
	25	5.26	7.08
	50	5.24	7.66
	75	5.33	8.19

Soil improvement

Under different agroforestry systems, increase in organic carbon, available nitrogen, phosphorus, potassium, soil microbial biomass carbon and dehydrogenase activity have been reported by several workers (Mishra *et al.,* 1985, Pathak, 1994, Rai *et al.* 2001, Yadava *et al.,* 2007). Soil improvement in *A. pendula* based agroforestry system is negligible in literature. However, Rai *et al.* (2003) reported increase in soil organic carbon, available nitrogen , phosphorus and potassium after 3 years of *A. pendula* based agrisilvicutlural system over initial values at 0-15 and 15-30 cm soil depth. The increase in OC, available N, P and K was 25.9, 1.4, 15.2 and 7.0%, respectively in 0-15 cm soil depth over initial values. Further, it was observed that increase in all the nutrients were higher at 25% pruning intensity compared to 50% pruning intensity at both the soil depths. This may be due to higher litter fall at 25% pruning height (0.50 t/ha) as compared to 0.39 t/kg in 50% pruning height.

Conclusion

A. pendula is a small, gregarious, dry deciduous tree having light spreading crown and strong roots. Its timber is very hard, tough, strong, durable and is equivalent to

teak in terms of transverse strength. It is an excellent fire wood as its calorific value is high (5300 k Cal/kg). It is distributed throughout the tropical Asia and Africa. In India, it is occurs in dry tropical forests and dry mixed deciduous forest of Rajasthan, part of Gujrat, Maharastra, Madhya Pradesh, Haryana and Bundelkhand region of Uttar Pradesh.

Table 2 : Effect of pruning on growth parameters of Black gram (Kharif, 2001)

MPTs	Pruning height (%)	Plant population (per m row)	No.of pods/ plant	No.of grains/ pod	Test Wt (g/100)
H. binata	10	16.74	7.27	5.34	3.61
	25	12.93	8.00	4.67	3.70
	50	17.94	6.87	5.67	3.74
	75	17.94	8.00	5.34	3.86
A. pendula	10	12.80	7.74	5.53	3.79
	25	11.40	6.40	6.13	3.71
	50	12.34	6.54	5.67	3.80
	75	12.67	7.60	5.60	3.81
A. latifolia	10	16.34	6.86	6.00	3.77
	25	12.06	7.86	4.60	3.81
	50	14.54	7.07	5.20	3.82
	75	14.34	6.00	5.47	3.85
Control		18.00	9.67	6.34	3.97

Single seed weight of *A. pendula* has vide variation ranging from 1 mg to 17 mg., the length, width and thickness of seed ranged from 4.66 to 7.00 mm, 3.28-5.68 mm and 1.06-2.06 mm, respectively. Viable seeds in this species is only about 15%. The germination can be increased by applying different treatments. Maximum increase of 92.5% can be obtained by soaker for 48 hours in aqueous solution of IBA (1000 ppm) followed by IBA solution of 500 ppm concentration. Two years old seedlings of this species was found better for higher establishment. This species is also propagated through natural regeneration or vegetative propagation by stem cuttings and air layering during spring season with IBA treatment of 400 ppm for stem cutting and 800 ppm for air layering of 24 hours. The growth of the species is also as it showed MAI of 0.32 for height at 5 years and 0.30 m at 10 years age grown in natural grassland having red gravelly soil. However, improved tissue culture raised material showed higher MAI of 0.42-0.51 m at 7.5 years age for height of *A. pendula* growing in silvipatoral system. There were no significant differences in growth parameters of *A. pendula* with different pruning treatments. For higher leaf fodder and fuel wood production pruning to be initiated during 4th year in *A. pendula* and pruning to be done at the 75% height of the trees. The nutritive value and digestibility of *A. pendula* leaves are good can be utilized by livestock for higher growth and production.

On the basis of above, it can be concluded that *A. pendula* may be utilized for growing in different agroforestry systems for utilization of marginal, sub-marginal and wastelands for getting forage, leaf fodder, fuel wood and timber production.

Future research thrust

Considering the potential of this species and based on the review obtained it is suggest that future line of research needs to be focussed on following :

- Identification of superior phenotypes/genotypes and collection of their germplasm.
- Vegetative and seed route production of planting material.
- Possibilities of boundary plantation of *A. pendula* genotypes should be explored to obtain higher yield of crops.
- Methods to increase seed germinability.
- Studies on soil nutrient dynamics under *A. pendula* based agroforestry system.
- Optimum pruning intensity to be evolved.
- Optimum spacing of *A. pendula* should be identified to increase yield of understorey crops.
- Suitability under Agroforestry – tree crop interaction
- Underground/rooting behaviour *etc*.

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