Reproductive biology and germplasm evaluation of *Acacia nilotica* (Linn.) Willd. ex Del. from North India

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Abstract

Acacia nilotica exhibits morphogenetic diversity in the form of three North West Indian varieties, namely, var. *typica*, var. *kauria* and var. *cupressiformis*. These are distinguishable on the basis of bole, crown, spine and pod characters. The present communication covers the observations on the reproductive biology and germplasm evaluation in these varieties. In spite of having ca 1/3-1.2 of flowers pre head with sterile pistils, trees produce numerous pods, and seeds per pod. Trees of var. *typica* from dry zones provide the best wood both as timber and fuelwood. For bark tans, older trees over 40 years of var. *typica* should be harvested. Gum yield is the highest in var. *cupressiformis* but var. *typica* produces superior quality gum. On the basis of various fodder characteristics and *in vitro* dry matter digestibility (IVDMD), var. *typica* produces the best quality fodder both as leaf and pod. For the majority of the economic attributes, var. *typica* is far superior to var. *kauria* and var. *cupressiformis*.

Introduction

Acacia nilotica (Linn.) Willd. ex Del. is very widely distributed in the arid and semi-arid regions of India. It forms extensive and generally pure forests, locally referred to under different names in different states of India as *Babul Savannah*, *Acacia Forests*, *Inundation Babul Forests*, *Babul Bans, Babul Meadows*, *Desert Thorn Forests*, or *Ravine Thorn Forests,* etc. Outside India, it grows well in subtropical to tropical regions of Asia, Africa, Australia and Caribbean. The species exhibits considerable morphogenetic variability in the form of different varieties/sub-species. Worldwide, 9 subspecies and 3 varieties (Brenan 1983) or 10 subspecies and 2 varieties are known to exist which show intensive hybridization among themselves. The species has a wide morphogenetic base and seems to constitute a complex with diploid (2n=26), tetraploid (2n=52), octoploid (2n=104) and 16-ploid (2n=208) cytotypes besides some aneuploid chromosome numbers, 2n=24, 44, 48. Three varieties, var. *typica*, var. *kauria* and var. *cupressiformis* detected by the authors in North West Indian taxa, can be easily identified in the field on the basis of their bole, crown, spine, leaf and pod characteristics (Singhal & Kaur 2004).

Acacia nilotica is one of the best multipurpose tree (MPT) species providing 1st class commercial timber (Pearson & Brown 1932), excellent ash free fuelwood with high calorific value (Krishna & Ramaswamy 1932; Trotter 1940; Pathak 1993), best quality charcoal (Patil *et al*. 2000), good fodder as leaf and pod (Singh 1982), quality gum (Dwivedi 1993), and a high percentage of bark tannins (Dwivedi 1993). Besides, the species is of considerable importance in agro-forestry and wasteland management for its ability to grow fast and fix atmospheric nitrogen. As a pre-requisite it is desirable to evaluate the morphogenetic diversity in the species with respect to various attributes of economic utility on variety basis. Various aspects of flowering phenology, floral biology, pollination mechanism and compatibility behaviour at variety level are also required in order to understand the breeding system of the species. Keeping in view its importance and wide morphogenetic base, different aspects of reproductive biology are essential to understand the breeding system. The present communication covers the reproductive biology and

germplasm evaluation of three varieties for North West India where these varieties are well distributed.

Material and Methods

To study reproductive biology and germplasm evaluation, seventy accessions belonging to var. *typica*, var. *kauria*, and var. *cupressiformis* were selected from the dry, semi-dry and sub-mountainous regions growing in the states of Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Uttranchal and Rajasthan (Table 1). The sample trees were screened for chromosome number, microsporogenesis, and pollen and seed fertility. Phenological observations for initiation of leaf and inflorescence primordia, time of peak blooming, and decline in flowering, were made from the marked individuals. For flower development, marked floral heads were observed at one day intervals for 50–60 days. Flower structure is based on wide sampling of 20–25 flowers per head in each variety. Time of anthesis, anther dehiscence and stigmatic receptivity was determined by observing the marked heads at 1 hour intervals. Healthy, glistening white and shining surfaced stigmas were considered as apparently receptive, while dull, pale coloured and shrivelled ones were assumed non-receptive. Pollen fertility was determined through the glycerol-acetocarmine mixture (1:1) and tetrazolium chloride (1%) staining method (Shivana & Rangaswamy 1992). Actual pollen viability was estimated by germinating pollen on a 1% agar medium supplemented with 10–12% sucrose solution. Number of pollen grains per anther per flower was determined by using the method suggested by Lloyd (1965). Number of ovules in the ovaries was counted by crushing the pistils on a glass slide in lacto phenol aniline blue. Pollination mode was determined by observing the trees in full bloom. Wind mode of pollination was confirmed by examining glycerine smeared glass slides for pollen, hung at different levels at all sides of the tree during peak flowering. For insect pollination, insect activity was examined at 1 hour intervals. The frequency, time and pattern of insect visitation were studied through visual observations. Insect visitors to floral heads were collected with a net, fixed in alcohol and identified. Self compatibility was determined through bagging unopened heads and examining the seed set. Seed maturation was used as an indicator of effective pollination and fertilization.

Table 1. Locations of sample trees of three varieties of *Acacia nilotica* in dry, semi-dry and sub-mountainous zones of North West India.

States	Zones	var. *typica* Locality	var. *kauria* Locality	var. *cupressiformis* Locality
Punjab	Dry	Bathinda, Faridkot, Ferozepur	Bathinda, Faridkot, Moga	–
	Semi-dry	Amritsar, Fatehgarh Sahib, Hoshiarpur, Ludhiana, Malerkotla, Patiala	Amritsar, Chhatbir, Hoshiarpur, Jalandhar, Ludhiana	Ballowal Saunkari
	Sub-mountainous	Anandpur Sahib, Garhshankar	Ghanaula, Ganguwal	Anandpur Sahib, Ganguwal, Jogewal, Mangewal, Mansewal
Haryana	Dry	Mandi Dabwali	–	–
	Semi-dry	Kurukshetra	Ambala, Pipli	–
	Sub-mountainous	Kalka, Panchkula	Pinjour, Surajpur	–
Uttar Pradesh	Sub-mountainous	Saharanpur	Saharanpur	–
Uttranchal	Semi-dry	Rampur, Roorkee,	–	–
	Sub-mountainous	Dehradun, Rishikesh	Haridwar, Rishikesh	–
Himachal Pradesh	Sub-mountainous	Naina Devi, Paonta Sahib, Una	Mandi, Naina Devi, Paonta Sahib	–
Rajasthan	Dry	Ganganagar, Hanumangarh, Kota, Raisingh Nagar	Hanumangarh, Kota	–

Wood quality as timber is estimated on the basis of moisture content (MC) %, specific gravity and weight density as per the method and formulae of Panshin and de Zeeuw (1980). Fuelwood quality is determined on the basis of calorific value using a Bomb Calorimeter (Adiabatic), and heat of combustion is calculated by using the following equation-

WT = HM, where

W = Water equivalent of bomb calorimeter
T = Rise in temperature
H = Heat of combustion of material in Cal. /g
M = Mass of sample in g

Fodder quality of leaves and pods was based on Crude proteins (CP), Neutral detergent fibers (NDF), Acid detergent fibers (ADF), Cellulose (C), Hemi cellulose (HC), Lignin, Ash contents and Tannins, as estimated per Vansoet's system of Analysis (1967). *In vitro* dry matter digestibility (IVDMD) is based on the *in sacco* technique of Tilley and Terry (1963). Gum yield has been estimated from the natural wounds/cracks and artificial incisions inflicted on the stem. Gum quality is determined on the basis of colour, with light coloured considered as of good quality. The bark tans from the boles and branches of young, mature and old aged trees were estimated every two months through the standard Indigo Carmine Titration Method (Anonymous 1957).

Results and Discussion

Acacia nilotica in North-West India exhibits morphogenetic diversity in the form of three varieties, namely var. *typica*, var. *kauria*, var. *cupressiformis*. The trees in each variety can be identified on the basis of crown, bole, spine, leaf and pod characters. The sample trees selected for germplasm evaluation and various aspects of flowering phenology, floral biology, pollination mechanism and breeding system were found to be sexual diploid (n=13) with normal meiotic course, high pollen fertility (more than 90%), and good pod and seed set.

A. Reproductive biology

Phenologically the species passes through a brief deciduous phase of 28–36 days during winters (January-February) and a long and staggered flowering period of 161–189 days with peak blooming during monsoon months of July-August. Flowering phenology phase is nearly the same in the three varieties except that the opening of floral buds is delayed by 15–20 days in var. *cupressiformis*. Wyatt (1982) opined that species with extended flowering phase would be at an advantage in term of probability of fruit set. Such a case can also be attributed to *A. nilotica* where fruit setting initiation is high (up to 26%) but a low percentage of fruit reach maturity (up to 4%). This seems to be the consequence of premature fruit fall at various stages of pod development owing to wind currents and pest attack of young fruits. The species bears pods biannually, first in October to December and for a second time during January to May. Pod set and maturation is lower for the first pod set, probably due to low temperature and frost conditions. Of the three varieties, trees of var. *typica* show relatively high pod set ($3.4 \pm 0.86\%$ to $4.8 \pm 0.98\%$) compared with the var. *kauria* ($1.00 \pm 0.79\%$ to $2.00 \pm 1.28\%$) whereas var. *cupressiformis* shows the lowest percentage fruit set ($0.30 \pm 0.20\%$). On provenance basis, trees growing in semi-dry zones show relatively high percentage of mature pods compared with dry and sub-mountainous zones. It has also been observed in this study that trees growing in populations and plantations bear higher number of fruits compared with the isolated individuals.

The small sized, tubular, and sessile flowers, with the odour of ripe lemon, are present in bright yellow globose and fluffy cymose heads, arranged in panicles. The heads are the largest in var. *cupressiformis* (1.38 ± 1.02 cm x 1.40 ± 1.00 cm), closely followed by var. *typica* (1.32 ± 1.10 cm x 1.38 ± 1.03 cm), whereas those of var. *kauria* are the smallest (1.25 ± 0.06 cm x 1.27 ± 0.09 cm). The size and number of flowers in a head is also the highest in var. *cupressiformis* (5.3 ± 3.0 mm x 3.5 ± 1.2 mm, 46 ± 2.14) and lowest in var. *kauria* (4.9 ± 0.8 mm x 2.0 ± 1.0 mm, 37 ± 2.70). Flowers in each variety are similar in structure. These are bisexual but a considerable number of these are functionally male due to the presence of a sterile pistil. The result, based on dissection of 1875 flowers from 50 heads (Table 2), depicted that frequency of such flowers ranges from 32.63% in var. *typica* to 49.25% in var. *kauria* and up to 57.00% in var. *cupressiformis*. The frequency of such flowers is relatively more in the basal position (69.95 to 88.25%) than those at the top (9.75 to 20.19%) and

Table 2. Data on number and position of flowers with sterile pistil in a head in three varieties of *A. nilotica*.

Variety	Total no. of heads dissected	Total no. of flowers dissected	Number & position of flowers in a head	% of flowers with missing carpel	Percentage of missing carpel (Total)	Percentage of functional carpel (Total)
typica	20	675	T=170 M=335 B=170	9.75 18.19 69.95	32.63	67.37
kauria	15	600	T=70 M=260 B=170	14.45 49.94 83.36	49.25	50.75
cupressiformis	15	600	T=140 M=320 B=140	20.19 62.56 88.25	57.00	43.00

T= 10 flowers in top position
M= Median flowers (remaining after T and B have been counted)
B= 10 flowers in basal position

middle (18.19 to 62.56%). Wyatt (1982) suggested that number of flowers and their arrangement in time and space determines the pollination level and fruit setting. Richard (1997) opined that aggregation of flowers in a head provide a greater reward per pollinator flight and a sufficient landing base for the insect pollinators, particularly the bees and butterflies that treat the head as one flower.

Flower structure is known to affect the pollination and breeding system of the species. Presence of small sized and tubular flowers in a head with long exserted stamens add to anemophilous pollination as has been reported earlier in *Plantago lagopus* (Sharma *et al.* 1990). However, the mass effect of flowers in bright yellow cymose heads with the odour of ripe lemon seems to play the role of a primary attractant for insect visitors, encouraging entemophily. A variety of insects visit the floral heads during peak blooming. Active pollination is achieved by the anther and/or pollen foraging bees (*Apis florea*, *A. mellifera*), wasps (*Polistes herbreus*) and butterflies (*Pieris brassicae*, *Danaus chryoppus*). The second mode of pollination involves rather passive contact by beetles (*Mylabrus purtulata*, *Meladora* sp.), black ants (*Solenopsis geminata*) and walkers (*Pyrilla perpusilla*). A small number (3) of Hymenopteran insects briefly visited the flowers during the study period but were not likely to be significant pollinators.

Apis bees are most active between 10.00–11.30 hr, which coincides with pollen availability i.e. the time of anther dehiscence (08.00–12.00 hr). The bees pay 16–24 visits and spend the maximum time of 24–30 s per visit. The wasps and a butterfly (*P. brassicae*) pay 8–11 and 6–7 visits respectively, and spend only 12–20 s per visit. Regarding the pollen load, honey bees and wasps carry 8–12 polyads, and a butterfly (*P. brassicae*) carries 4–6 on its body parts. Insects such as beetles, black ants and walkers act as minor pollinators carrying only few polyads. The arrangement of flowers in an inflorescence has a profound effect on the types of insects involved in pollen transfer. In *Acacia nilotica*, the opening of flowers is centrifugal and is suited to bees (mellitophily) and butterflies (psychophily) which move from the centre of the head towards the periphery.

Richards (1997) opines that opening of flowers and pollen presentation directly affect the pollinator flight patterns and hence pollination success in the species. In *A. nilotica*, 80–90% flowers in a head open during night (18.00–24.00 hr) and all the anthers in a flower dehisce synchronously the next morning between 8.00–12.00 hr. As a result the pollen is presented to the visiting insects *en masse* ensuring high pollination success. Furthermore, the considerable number of functionally male flowers (32.63–57.00%) serves to attract the pollinators and increase pollen flow in the population.

Pollen grains in the species are present in the form of 16-celled polyads which are of *Enterolobium*-type, with no significant variation in size in three varieties (48.07 ± 1.12 μm to 50.40 ± 1.08 μm). The individual pollen grains are small sized ranging from 11.92 ± 0.27 μm (var. *kauria*) to 12.26 ± 0.31 μm (var. *typica*). Apparent pollen

fertility is quite high (92.13 ± 3.44% to 97.89 ± 1.02%), and higher during peak blooming (Table 3). The pollen viability is low during the initiation (83.19 ± 2.81% to 93.42 ± 2.03%) and decline of flowering (70.00 ± 1.98% to 80.11 ± 1.01%). Actual pollen viability, as estimated through germination, ranges between 58% to 65%. Pollen viability decreases with storage from 43.75% to 3.12% and pollen fail to germinate beyond 7 days of storage. Pollen tube length also decreases from 120 μm to 9 μm in stored pollen grains.

The pollen grains are effectively transferred by the anther and pollen foraging bees, wasps and butterflies. Some pollen grains are also transferred through wind. However, actual examination of seventy two stigmatic styles reveals that only one or two polyads were present on these small sized stigmas. It has been observed that after half an hour of polyad transfer the stigmatic styles show watery secretion, which helps in adhesion and germination of individual pollen grains.

Pollen – Ovule (P/O) is another indicator of pollination and breeding system of the species. On the basis of P/O ratio (562.50–625.00), the species falls under the category of facultative out-crosser in spite of it being predominantly xenogamous. According to Cruden (1977), P/O ratio in the members of Asclepiadaceae and Mimosaceae are exceptions in the xenogamous group. In these families, pollen grains are grouped in pollinia or polyads, and the criteria for categorization of breeding system is not the P/O ratio but the ratio of pollen grains in a pollinium or polyad and the number of ovules per ovary. In *A. nilotica* this ratio is 1:1 (16 pollen per polyad and 16 ovules per ovary) indicating that the species has good pollination success owing to the excellent relationship between number of pollen and number of ovules.

Little work has been done on the level of self pollination and degree of self incompatibility in the species (Tybrik 1989). Mandal *et al.* (1994), on the basis of enzyme analysis, suggested the species was self compatible and that 60% of the seeds are set through self pollination. Present studies revealed that natural self pollination in a flower is avoided due to herkogamy as the stigma is at a higher level than the stamens. Selfing through geitonogamy is also not successful, because from 675 heads bagged containing approximately 27,000 flowers, only 11 pods were set. In spite of the fact that a considerable number of flowers in a head have a sterile pistil, trees in each variety produced a good number of pods and seeds per pod at least during the second phase of fruiting. Such reproductive success can be attributed to effective pollen transfer and an excellent correlation between number of pollen grains per polyad and number of ovules per ovary. Out of three varieties, var. *typica* showed better reproductive success with respect to seeds (27,472 ± 58) whereas var. *cupressiformis* showed relatively poor fruit bearing capacity and lesser number of seeds (9600 ± 28). This may probably be due to the fact that var. *typica* exists in populations and trees of var. *cupressiformis* as isolated individuals.

Table 3. Pollen fertility in different varieties of *A. nilotica* at different phases of blooming from dry, semi-dry and sub-mountainous zones of North West India.

	Zone/s	Pollen Fertility (%)		
		Initiation of flowering	Peak blooming	Decline of flowering
typica	Dry	93.48	98.24	78.75
	Semi-dry	95.88	98.58	81.20
	Sub-mountainous	90.90	96.85	80.38
	Mean	93.42±2.03	97.89±0.74	80.11±1.01
kauria	Dry	84.35	94.15	77.94
	Semi-dry	88.76	96.37	78.11
	Sub-mountainous	85.49	92.86	73.30
	Mean	86.20±1.86	94.46±1.44	76.45±1.52
cupressiformis	Sub-mountainous	83.19±2.81	92.13±1.69	70.00±1.98

B. Germplasm evaluation

The species in India is recognised as one of the best MPT species as a source of timber, fuelwood, fodder, gum, tannins and for other minor purposes. The three varieties show different values for different parameters of these economic attributes.

I. Wood quality

Previously, Pearson and Brown (1932), Rao and Purkayastha (1972), Kaushik *et al*.(1984), Tewari and Rajput (1987), Shukla *et al*. (1990) and Purkayastha (1996) studied the physical and mechanical properties of wood. In the present study wood quality was estimated both as timber and fuel wood.

(i) Timber: The timber quality was determined on the basis of MC%, specific gravity (green and OD) and weight density. MC% in the species ranged from 46.31% to 69.43%. Negi (2000) also noticed a wide range of MC% in the trees growing under the same locality in populations of Haryana. On variety basis, average MC% was highest in wood of var. *cupressiformis* (69.43 ± 2.04%) and lowest in var. *typica* (53.34 ± 7.10%). MC%, as high as 73.26 %, was recorded in some trees of var. *cupressiformis* growing in Hoshiarpur (Punjab). On the other hand, a relatively low MC% (44%) was recorded in some trees of var. *typica* from Hanumangarh (Rajasthan). On provenance basis, trees growing in sub-mountainous zones contained relatively high MC% (63.07 to 69.43 %) as compared to those growing in semi-dry (50.65 to 64.11 %) and dry regions (46.31 to 48.77 %).

The wood of var. *kauria* had the highest specific gravity under green conditions (0.77 ± 0.04) compared with that of var. *typica* (0.69 ± 0.16). Specific gravity as high as 0.92 was recorded in the wood of some trees of var. *kauria* growing in Hanumangarh (Rajasthan). However, some individuals of var. *cupressiformis* growing in Hoshiarpur (Punjab) showed very low specific gravity (0.49). Specific gravity of OD wood was highest in var. *typica* (1.09) and lowest in var. *cupressiformis* (0.80). The highest specific gravity of OD wood (1.31) was recorded in the wood samples of var. *typica* collected from the dry regions of Bathinda (Punjab) and Ganganagar (Rajasthan). Specific gravity as low as 0.69 was recorded in trees of var. *cupressiformis* from Ganguwal, Ropar (Punjab). On provenance basis, wood of trees growing in dry areas had a higher specific gravity compared to those growing under semi-dry and sub-mountainous zones.

On a weight density basis, wood of var. *typica* was the heaviest (1.39 ± 0.04 g/cc) compared with that of var. *kauria* (1.17± 0.01 g/cc) and var. *cupressiformis* (1.15 ± 0.01 g/cc).

On the basis of these parameters, trees of var. *typica* growing in dry and arid zones yield the best quality timber. Troup (1921) has also inferred that wood of var. *telia* (var. *typica*) has a better reputation than other varieties.

(ii) Fuelwood: The wood of *A. nilotica* provides good fuel due to high calorific value and excellent burning quality with gradual burning. Density of smoke during burning is very low, and moreover, it produces no sparking or cracking during burning (Dwivedi 1993). The heating power of wood of *A. nilotica* is very high ranging between 4236.55–4950.75 Kcal/Kg. Among the three varieties, var. *typica* yields the best fuelwood with highest calorific value (4875.91 Kcal/Kg ± 53.14) and var. *cupressiformis* (3900.25 ± 50.22) the lowest. On provenance basis, trees of dry zones provide better quality fuel wood than those of semi-dry and sub-mountainous zones.

II. Tannins

'Babul' bark is the most important bark used by the tanneries in Northern India because it is cheap and abundant, and is easily obtained as a by-product after the trees are felled for fuel or timber (Trotter 1940; Mehta 1981). Bark tans from bole ranges between 12 to 20% with old trees containing more tannins (Mehta 1981; Anonymous 1985; Dwivedi 1993). Present results also indicated that average tannin content was high and variable (17.80 to 38.07%) with some old aged trees of var. *typica* from semi-dry regions containing as high as 40.87%. Trees of var. *typica* contained the highest percentage in both bole (21.89 to 38.07%) and branches (9.81 to 12.34%). Whereas trees of var. *cupressiformis* had the minimum quantity of bark tans, 17.80 to 24.69% and 7.37 to 10.85% in boles and branches, respectively. The content of tannins in the bole (18.76 to 29.54%) and branches (8.75 to 11.00%) of mature (11–20 yrs old) trees was significantly higher compared with 5–10 yrs old young trees. The amount of bark tans also varied significantly in different geographical and

climatic regions where sample trees were growing. The bark tans in the bole and branches of all age group trees were much higher in trees growing in semi-dry regions compared with those of dry and sub-mountainous regions. On the basis of data collected at 2-month intervals, it was observed that quantity of bark tannins is highest during rainy months (July-August). The next best season for tans from bole is during winter months (January-February), whereas for branches tannins are the highest during March–April.

Thus, mature var. *typica* trees collected during April-May or January-February provided the best yield.

III. Gums

'*Babul*' gum exudes from natural wounds or cracks in the stem bark mainly during the hot and dry months of March-June. But the natural gum oozing process is slow, taking nearly a month or so. The average gum yield per year in trees of var. *typica, kauria* and *cupressiformis* was 17.33g ± 4.10, 11.67g ± 3.29 and 22.00 ± 6.16 g, respectively. However, it was observed that tapping through artificial incisions stimulated the gum flow, taking 5–7 days in dry, 10–12 days in semi-dry, and 18–22 days in sub-mountainous zones. The gum yield in the species can be enhanced from 3–17 times by inflicting incisions on the stem. It was also noticed that a blaze of 35x10 cm exuded the highest quantity. The freshening of these cuts at regular intervals with a solution of N/5-N/15 NaOH further enhanced the gum oozing process and yield, as has also been noted earlier by Dwivedi (1993) and Shiva *et al.* (1998).

The present study of three varieties revealed that gum yield also depended upon the age of tree, the area/provenance where the trees were growing, and size of incisions. The trees between the ages of 11–20 yrs gave the maximum yield. Beyond 20 yrs of age the gum yield reduced significantly. Very young (5–10 yrs) and very old trees (>40 yrs) produced only negligible quantity of gum as has also been reported earlier (Anonymous 1985; Dwivedi 1993). On variety basis, the average yield from natural wounds and artificial incisions was highest in var. *cupressiformis* and lowest in var. *kauria*. It was also observed that trees growing in dry regions yielded more gum compared with those of semi-dry and sub-mountainous zones. The colour of gum ranged from pale white to yellowish or dark reddish

brown to almost black, depending upon the age of tree and presence of tannins in the bark. The young trees produced light shaded superior quality gum compared with the old aged trees. The trees of var. *typica* and var. *kauria* produced better quality gum with lighter colour whereas those of var. *cupressiformis* yielded poor quality gum with dark brown colour.

IV. Fodder

Acacia nilotica yields an excellent fodder both as leaf and pod, and trees are extensively lopped for the purpose (Singh 1982; Verma & Mishra 1989; Dwivedi 1992, 1993). The fodder quality of leaves and pods was determined on the basis of various constituents and IVDMD. The leaves contained relatively higher CP contents (18.50 to 20.15%) compared with pods (12.25 to 12.68%). Cellulose and hemicellulose were present in good quantity, with pods containing relatively higher cellulose contents (12.80 to 18.76%) compared with leaves (6.98 to 9.25%). However, the trend for hemicellulose is reversed, being much higher in leaves (12.00 to 18.05%) than pods (7.95 to 12.90%). At variety level, the cellulose in leaves was significantly higher in var. *typica* (9.28 ± 1.17%) compared with var. *cupressiformis* (6.98 ± 1.00%). But in pods, the amount of cellulose was higher in var. *cupressiformis* (18.76 ± 1.17%) compared with var. *kauria* (13.25 ± 0.42%) and var. *typica* (12.80 ± 0.97%). As far as hemicellulose is concerned, the amount in leaves was the highest in var. *kauria* (18.05 ± 2.54%), but in pods the hemicellulose was the highest in var. *cupressiformis* (12.90 ± 0.63%).

The lignins, which are known to affect the availability of cellulose and hemicellulose in fodder, were relatively low in leaves (5.50 to 6.60%) compared with pods (6.35 to 8.20%). The leaf lignins were higher in var. *kauria* (6.60 ± 1.12%) whereas for pods the amount was highest in var. *cupressiformis* (8.20 ± 0.89%).

Ash content was much higher in leaves (11.18 to 12.80 %) compared with pods (5.80 to 7.24 %). At variety level, var. *cuperessiformis* had the lowest ash content in leaves (11.18 ± 0.65%) and var. *typica* had the highest amount (12.80%). But for pods, the ash contents were the highest in var. *typica* (7.24 ± 0.76%) and lowest in var. *kauria* (5.80 ± 0.13%).

The NDF and ADF were much higher in pods compared with leaves. At variety level, the NDF and ADF

from leaves was significantly higher in var. *kauria* and lowest in var. *typica.*

Tannins, which are found to affect the fodder quality, were higher in pods (5.65 to 6.20%) compared with leaves (4.30 to 5.00%). The leaves of var. *typica* contained the lowest quantity of tannins compared with other varieties. Leaves of all three varieties showed higher IVDMD compared with pods. At variety level, leaves and pods of var. *typica* were the most digestible with 79.65% and 70.65% IVDMD, respectively.

Overall evaluation of germplasm for wood as timber and fuel wood, in three varieties from dry, semi-dry and sub-mountainous zones reveals that trees of var. *typica* growing in dry and arid zones of North West India provide the best quality wood both as timber and fuel wood owing to low MC%, high specific gravity and weight density, and high calorific value. On the other hand, var. *cupressiformis* yields poor quality wood due to high MC%, low specific gravity and weight density. The better quality of wood as timber and fuel wood in var. *typica* can be attributed to low vessel frequency, high fiber frequency and greater fiber wall thickness.

Among the various tanning materials used in tanneries in Northern India, bark tans of *A. nilotica* are the most important as these are usually obtained as a by- product after the trees are felled for timber or fuel wood. Of the three varieties, var. *typica* yields the minimum quantity of tannins, followed by var. *kauria,* whereas var. *cupressiformis* gave the maximum bark tans. On age basis, old age trees (>40 yrs) should be preferred for bark tans. Also it has been inferred that to get good yield, trees must be harvested for bark either during rainy (July-August) or winter months (December-January).

'Babul' gum is an important article of local importance and is used as a substitute of *'true gum arabic'*. The gum yield is the highest in var. *cupressiformis,* whereas var. *kauria* yields the lowest quantity. Trees growing in dry zones yield more gum compared with those of semi-dry and sub-mountainous zones. Gum yield can be enhanced up to 17 times by inflicting incisions of the size of 35 x 10 cm on the bole. Yield can be enhanced further if these cuts are freshened at regular intervals with N/5-N/10 NaOH. Trees of var. *typica* yield the higher quality, lighter coloured gum compared with that obtained from the trees of var. *cupressiformis*. It

has been also observed that young aged trees in all the varieties yield lighter coloured gum. If quality is not under consideration and darker coloured gum serves the purpose (as an adhesive), even the old aged trees can be tapped.

On the basis of higher amount of CP, Cellulose, HC, and ash contents, and low amount of NDF, ADF, lignins and tannins, coupled with good IVDMD, *A.nilotica* yields the best fodder and is equivalent to *Grewia optiva* and *Morus alba*. Variety *typica* produces the best quality fodder whereas var. *kauria* gave the poorest quality fodder.

From the above account it has been inferred that for the majority of the parameters, var. *typica* is far superior to var. *kauria* and var. *cupressiformis*, and would be recommended as a preferred variety for plantations.

Acknowledgments

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