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Multipurpose Tree Acacia - Potential for Domestication in India

KEYWORDS

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Acacia mearnsii

Acacia mearnsii used for shade in tea estates, India © CSIRO Forestry and Forest Products

Acacias and a dirt-deveil in the Chalbi Desert of northern Kenya.
Photo by Rob Marchant.
These are frequent events in sandy areas in summers (India).

Acacia aneura (mulga) is widely distributed in the Australian arid zone. Its foliage is browsed by ruminants especially in times of drought, and its wood is valued for turning and carving

Half-moons around newly planted Acacia seedlings catch and retain rainwater (Photo by T.F. SHAXSON)

Planting pits have been introduced successfully in Zambia as a conservation practice for smallholder farmers, who do not have fertilizers or tractor services available to them.

The most generally accepted classification of Acacia recognizes three large subgenera i.e. subgenus Acacia (120-130 species), subgenus Aculeiferum (180-190 species) and subgenus Phyllodineae (940 species). Acacia is one of the largest genera of flowering plants, widely distributed mainly in Australia, Africa and Asia and with a multitude of products extensively utilized by humans and wildlife. The genus is adapted to growth on many types of soil, a prominent component of many forest ecosystems and, as a nitrogen (N) fixing legume, apparently contributes substantially to natural N cycling. Although millions of hectares of land have been planted with acacias, especially for plantation and farm forestry and rehabilitation of degraded landscapes (Chaer et al., 2011), many authorities consider that the genus is underutilized. The literature that we surveyed gave us the very strong impression that the symbiosis of acacias with root-nodule bacteria, and their capacity to fix atmospheric nitrogen as a consequence of that association, is also underutilized.

Acacia nilotica (L) was introduced into Australia in the 1890s for shade, fodder and ornamental purposes (Bolton 1989). In its native range there are nine subspecies of A. nilotica distributed in an arc from northern South Africa to the north and east across to eastern India (Hill 1940). In Australia, A. nilotica was well established in Queensland in the Bowen and Rockhampton districts by 1926, and was being actively promoted as a source of shade and forage for sheep while being noted as a problem in cattle country (Pollock 1926). The plant was not declared noxious under the Rural Land Protection Act until 9 March 1957. The factors of most importance are the expected increases in water-use efficiency of A. nilotica due to increased atmospheric CO2 concentrations, allowing it to invade more xeric sites further Inland and increased temperatures, allowing it to complete its reproductive life cycle. Likewise, increased growth potential could also offer the opportunity of mixing pastoral and agroforestry activities on the same land, mitigating the effects of increasing CO2 concentrations, or fuelling local bioenergy projects. Undisturbed remnant native shrub lands, woodlands and forests may limit invasion by A. nilotica, due to the reported shade intolerance of the species (Miller 1996), and the lack of sheep or cattle grazing (Tiver et al. 2000).

Australian acacias were initially introduced in sub humid subtropical areas and at higher altitudes in the tropics. In Asia, A. decurrens, A. dealbata and A. melanoxylon were introduced into Tamil Nadu, India in the 1840 as fast growing trees to supply fuel for the army. They were subsequently used as shade trees on the tea estates and for utility timber. The black wattle, A. mearnsii, which was introduced into South Africa (1864), was also planted in Indonesia (1880) and Sri Lanka (1890). Its bark provided a superior source of tannin and tanning industries based on black wattle plantations emerged in South Africa, East Africa, Brazil, India and Indonesia (Sherry 1971; Brown and Ho 1997). The planting of acacias as exotics in the lowland humid tropics has taken place more recently. Acacia auriculifonnis originating in Australia, Papua New Guinea and parts of eastern Indonesia has been planted as an exotic in Asia for more than 60 years. It was introduced to Malaysia in 1932, to Thailand in 1935 and was planted in commercial plantations in West Bengal, India in 1946. It was used principally as an ornamental, for fuelwood or to revegetate denuded land following mining. Although A. auriculiformis was asuccessful exotic in tropical Asia, the introduction of A. mangium into Sabah, Malaysia from Australia in 1966 that created the major interest in tropical Acacias. Initially introduced as a plant in firebreaks to protect pine plantations, its rapid growth suggested its potential for wood production and it was planted in Malaysia (Yap 1987). There was recognition in the 1970s and 1980s that Acacias from Australia and adjacent countries had potential as highly adaptable multipurpose trees to provide fuelwood and other products in rural development as well as for industrial wood production.

A. confusa, a native to China, is planted widely along roadsides and on farms. It is used as a shade tree in tea gardens and for fuelwood, farm tools, furniture, and house-building (Zheng and Yang 1993). A. auriculiformis was introduced in 1961 (Pan and Yang 1987) used for afforestation programs, soil and water conservation plantings in the uplands, fuel wood, farm tools, biofertiliser and as a source of pollen for honey bees. A. mangium is expected to provide raw material for high quality paper pulp (Wang et al. 1994). A. crassicarpa and the shrubby A. holosericea are also planted on a small scale, the latter sometimes in mixed plantations.

In India, since the introduction of A. auricul!formis to West Bengal in 1946 it has been planted in many places, ranging from coastal sands to higher altitude lateritic soils in areas having from 500 to 7000 mm of rainfall annually. It has been a major species for afforestation in the southern Indian states and is most widely planted in Karnataka where it is of interest to the pulp and paper industry (Bulgannawar and Math 1991). The tolerance of A. auriculiformis to a wide range of site conditions, including coastal sands and waterlogged soils, make it a major species for reforestation of degraded lands, usually as a cover crop and as a source of fuel wood (Kushalapa 1991; Nadagoudar 1993). It is used on wasteland such as coal mine spoils and paper mill sludge (Prasad 1991; Hocking 1993). In Tamil Nadu, A. holosericea has grown well on dry lateritic sites and is planted extensively in that region (Jambulingam 1986). The area of exotic acacias planted in India has been steadily increasing mainly under A. auriculiformis (Sharma and Florence 1997). Seed from A. auriculiformis plantations around Midnapore, West Bengal has been traded internationally.

Indigenous forests in many developing countries are heavily utilized for a wide variety of products. The pressure on forests for the supply of essential commodities is resulting increasingly in declining resources and environmental degradation. Thus there is a need to locate species, particularly with multipurpose characteristics, to supplement production from indigenous forests. However, for a multipurpose tree such as Acacia senegal, desirable tree criteria may include: fast growth, drought resistance, high gum yield, production of high quality non variable gum, and resistance to pests and diseases. The improved materials produced will have to be integrated into a viable production system. Wiersum (1996) suggested the tree morphology will need to be manipulated as it is a major component of the plant's ability to produce in its immediate environment. Many Acacia species have characteristics that make them highly suitable for introduction into tropical and subtropical countries, particularly in situations of low soil fertility and aridity (Boland and Turnbull 1981). Trees and shrubs are valuable components of grazing lands, and in most arid and semi-arid areas domestic ruminants obtain significant quantities of food from them (UNESCO 1979). Trees taller than about 5 meters (including most members of the genus Acacia) provide shade and shelter for livestock, and can also keep fodder out of their reach until it is cut down. Trees also provide larger quantities of firewood and building poles than shrubbier plants. The canopies of woody plants protect soil from erosion by wind and raindrop impact and their deep roots act as soil stabilizers (Hall 1972) and nutrient pumps (Everist 1969); therefore they can also contribute indirectly towards sustaining grazing land productivity. In addition, the root nodules of most Acacia spp. fix atmospheric nitrogen. In Indonesia, both government and private sectors are putting a major effort to rehabilitate grasslands infested by the weed Imperata cylindrica; this provides employment opportunities directly or indirectly to local people. In Sabah, Malaysia and the Philippines, the concept of tree farming has been introduced to farmers near pulp and paper mills. Farmers are encouraged to grow trees through free distribution of seedlings and/or guaranteed purchase of their harvest. A. tortilis, A. nilotica and A. canophylla with grasses are few examples of most viable silvi-pastoral systems in shifting sand dune areas (Tokey 1988). Furthermore, afforestation of degraded lands has a large potential of soil carbon sequestration, and realization of this potential is a challenge in the mitigation of climate change (Lal, 2004). However, lack of knowledge on the biology and ecology of indigenous species and their adaptation to environmental stress limited their use in the afforestation programs (Gebrekirstos et al., 2006). The process of domestication which has seen A. mangium (since 1966) and A. crassicarpa (since 1984) come from obscurity, into experimental trials and become species of major commercial importance, has involved plantation managers and researchers from many countries. The challenging process of exploration and manipulation of the wild genetic resource to derive uses and products for maximum social benefit is regarded as domestication. It is an ill-defined process but it has a clear beginning (the wild plant), a middle (human intervention via propagation, selection and manipulation) and an outcome (enhanced human benefit). It begins with the original variability in the natural forest and ends in productive plantations (Libby, 1973) and full tree domestication includes identification and characterization of its germplasm resources; the capture, selection and management of genetic resources; and the regeneration and sustainable cultivation of the species in managed ecosystems (Leakey and Newton, 1994). Provided the principles of sustainable plantation management are respected, acacia plantations offer an economically, socially and environmentally attractive option for supply of high quality raw material.

This review aims at an unbiased assessment of the prospects of domestication of the multipurpose tree Acacia.

Nitrogen enrichment of soil

There are reports that Acacia species may fix nitrogen (N) unto 200 kg per hectare per annum. Most measurements of acacia nitrogen fixation had been made in natural ecosystems whereas the N fixed by other tree legumes had been measured in anthropogenic ecosystems. In natural ecosystems, N cycling takes place at a relatively rapid rate aided by diverse macro- and micro flora that decompose leaf litter above ground and root fragments and non-living components of the soil community underground. The organic N released by these processes is transformed to nitrate by nitrifying organisms. Nitrate is well known as an inhibitor of legume nodulation and N fixation. Where natural forest has been cleared for agriculture or silviculture, N cycling is much reduced, with lower rates of nitrification legume N fixation would be inhibited less than in natural ecosystems. Therefore, there is good reason to believe that the intrinsic N-fixing capacity of Acacias is just as great as for other tree legumes.

Most of the world's Acacias grow in forests or woodlands. For reasons of microbial ecological competition with populations of Acacia rhizobia already resident in those soils, the chances of successfully and permanently introducing more- effective strains are nil. So there is probably little that can be done to increase the N fixation by Acacias in natural ecosystems, except to improve their vigor. Following timber harvesting or wild fire in ecosystems where they occur, Acacias are frequently the primary recolonising species and may be dominant for many months or even several years. Any strategy that might be used at this time to increase their N fixation would be of subsequent benefit to non-N-fixing components of the ecosystem. An apt example is the contribution made by Acacia species as natural understorey components of Eucalyptus forest ecosystems in Australia (Adams and Attiwill 1984; Hansen and Pate 1987a). An appropriate strategy would also assist in the replenishment of the total pool of soil N which occurs when the quantity of N removed as plant (or animal) product is less than the amount of fixed atmospheric N that remains behind in legume residues. Nodulation in A. senegal has only been reported during the seedling stage (Ndoye et al. 1995). Attempts to find the nodules in the roots of large trees seem to have consistently failed (Masutha et al. 1997). Acacia rhizobia are, widely distributed as the Acacia species themselves. Indeed, they sometimes occur spontaneously in anthropogenic environments, e.g. landfill in Hong Kong (Chan et al. 1998). Nonetheless, there are many soils where the population density is so low as to pose a threat to the establishment of N-fixing trees (Thrall et al. 2000). Thies et al. (1994) put forward a unique proposal for predicting the need for inoculation on a regional basis using a geographical information system. Used judiciously according to need and performed properly, legume inoculation is a significant agency for improving plant productivity and soil fertility.

Where Acacias are used in plantation and farm forestry, there is a great untapped potential for exploiting the symbiosis. A. mangium seedlings inoculated by soil enrichment were well nodulated, showed impressive growth responses and continued to fix N in the most compelling reports of strain effectiveness trials in the field (Galiana et al. 1990, 1994, 1996, 1998) in West Africa. In most parts of the world, where manufacture of mixed-strain legume inoculants is very often standard practice, host/rhizobia specificity is not a problem to nodulate and fixes nitrogen with the complete range of Acacia species in demand for plantation and farm forestry. Smith and Daft (1978) suggested a scope for dual inoculation with rhizobia and mycorrhizal fungi to remove other nutritional constraints. Combined mycorrhiza and root-nodule bacteria may synergistically stimulate N fixation in legumes growing in soil that is deficient in plant-available P (Dela Cruz and Yantasath, 1993; Beniwal et al., 1992; 1995). Acacia species can reverse degradation process by stabilizing soils through development of extensive root systems. Once they are established, plants increase soil organic matter, lower soil bulk density, and moderate soil pH and bring mineral nutrients to the surface and accumulate them in available form. Their root systems allow them to act as scavengers of nutrients not readily available. The plants accumulate these nutrients; redeposit them on the soil surface in organic matter from which nutrients are much more readily available by microbial breakdown. Larger amounts of N are probably transferred when tops are incorporated into the soil or after being transformed into farmyard manure. N transfers are considerable for legumes that are ploughed in as green manure. The same is true for trees that shed large quantities of leaves and fruit. Thus trees appear to be good candidates for mixed cropping systems. However, use of trees results in competition for light and water and allelopathy.

Sulphur and some micronutrients are common limiting factors to N2 fixation and legume productivity in the poor acid soils of the tropics and sub- tropics (Franco, 1977). It has been the classical recommendation of use as 'starter' nitrogen for the growth of legumes. Otuba (2012) reported higher growth rate of both A. senegal and A. sieberiana seedlings (2 months) in unfertilized soil substrate than fertilization with a pure ammonium nitrate solution lacking other nutrients important for growth. However, field evidence of beneficial effects are not common at least for grain legumes. The use of rhizobia is just one of the items in a package of practices for legume growth and production. Thus, it must be promoted together with a long series of other inputs and agronomic factors. In many places it is of little use to promote the isolated application of rhizobia inoculant if, for example, lime and/or phosphorus are not applied on account of a lack of knowledge.

Plant growth, nodulation and nitrogen fixation are impaired at high pH by induced deficiencies in manganese, iron, boron, soil salinity, and anionic imbalances (Graham and Chatel, 1983). In alkaline or sodic soils, recommended management practices are: addition of gypsum or organic matter. After nitrogen, phosphorus is most generally the limiting nutrient in tropical soils and some species (Acacia holosericea) are more efficient in using phosphorus than the others (Cornet et al. 1985). As with soil acidity, an appropriate strategy could be the selection of both host plants and associated Rhizobium. Both calcium and magnesium are essential for the host plant and the symbiotic bacterium. A change in the Ca/Mg ratio can reduce the accessibility of either nutrient. An imbalance is generally induced by high applications of lime or potassium fertilizers (Munns 1977). The effect of potassium on N fixation is indirect, through the host physiology (Andrew 1977). In soils, low in productivity in the tropics, it is common to find high levels of available K and no response to fertilization. This may mislead the farmer for not using the fertilizer.

In Senegalese conditions, nitrogen uptake was estimated to be as follow 79-132 kg N/ ha for pearl millet; 74-84 kg N / ha for rice; 134 kg N /ha for sorghum; and 121-13 kg N /ha for maize (Blondel, 1971). In the Sahel, continuous dry-season cropping with sorghums and millets has been practiced beneath A. albida without reductions in yields or additions of fertilizers (Porteres, 1954). Nitrogen-fixing plants, essentially legumes, take a part of the nitrogen they require from the atmosphere, the other part being provided by the soil. When nitrogen fertilizers are available, soil nitrogen levels are maintained or improved by applying these industrially-fixed nitrogen sources. Intensive agricultural systems has certain limitations i.e. increasing cost especially in developing countries, low yields from leaching and denitrification, especially in tropical conditions, and pollution of underground water by nitrates. The other ' alternative' for maintaining or improving the nitrogen content in soil is to exploit nitrogen fixation. In fact, it would be wiser to develop management practices based on the integrated use of industrial and biological nitrogen fixation. Role of exotic or native species in reclamation needs careful consideration as newly introduced exotic species may become pests in other situations. Therefore, candidate species for vegetation should be screened carefully to avoid becoming problematic weeds in relation to local to regional floristic. For artificial introduction, selection of species that are well adapted to the local environment should be emphasized. Indigenous species are preferable to exotics because they are most likely to fit into fully functional ecosystem and are climatically adapted (Chaney et al., 2007). Many N,-fixing trees are cross-pollinated so that the genetic heterogeneity of individuals is considerable. This characteristic complicates germplasm exploration and selection but it can be exploited by screening the best clones, a technique that implies that clonal propagation methods are available.

Fodder Potential of Tree Species

The use of trees and shrubs as fodder for livestock offers several advantages relative to pastures in some environments. They are less susceptible than pastures to seasonal variation in moisture availability, temperature (frosts and desiccation) and fire. They may be more readily established and maintained in dry environments than pastures and they are capable of providing vital food supplies to stock at critical times during the year. In areas suitable for pasture production, browse material may provide a useful supplement to pasture in terms of minerals, energy and, at certain times of the year, protein. Areas where good pasture growth is difficult to achieve, particularly the arid and semi-arid zones of the world « 180 days/year for pasture growth), will be the areas with greatest interest in fodder trees. For example, 59070 of the total meat production and 72070 of the total milk production of Africa comes from arid and semiarid zones and in these areas that pastures are severely degraded (Mahadevan 1981).

Nutritive Value- Composition of Acacia fodder

The leaves of phyllodenous acacias tend to have higher crude fibre, lower crude protein and phosphorus content and lower organic palatable, did not increase live weight significantly (68 to 88 g), suggesting that the nutritive value of the unmilled pods was little better than dry season grazing. In Africa, much attention has been given to the nutritive value of pods. In Australia, there are fewer reports of nutritive value, but mulga pods are much sought after by sheep, either on the trees or after they have ripened and fallen (Everist 1969). Acacia leaves, flowers and pods of several Acacia spp. contain Tannins and potentially toxic compounds. Poisoning is not common and stocks are only likely to be affected if they consume abnormally large quantities of components containing the toxins. This usually occurs when the animals are hungry or are unfamiliar with the plant. The concentrations of toxins vary with plant part, stage of growth and geographical location (Hall 1972). Hydrogen cyanide is possibly the most serious toxin occurring in acacias; it appears that this poison is released when two compounds, in the plant a cyanogenic glycoside and a hydrolysing enzyme react in the animal's digestive tract. In ruminants, the rumen contents tend to buffer the absorption of cyanide. Cyanogenesis was limited to certain sections of the subgenus Phyllodineae; most cyanogenic (Forty-three) species were in section Juliflorae and two in subgenus Acacia (Maslin et al. 1988). The cyanogenic glycosides in subgenus Phyllodineae (Juliflorae) are prunasin and/or sambunigrin, derived from phenylalanine, whereas those from two species of subgenus Acacia are proacacipetalin, derived from leucine (Maslin et al. 1988). The oil from acacia species consists mostly of polyunsaturated fatty acids (62% linoleic acid), with 20% monounsaturated fatty acids (18% oleic acid), and 18% saturated fatty acids (Brown et al. 1987). The seeds of Acacia victoriae contain 17% protein (Brand and Cherikoff 1985). Many wattle seeds contain proteinase inhibitors and must be heated before being consumed in order to denature these potentially toxic compounds. Others contain non-protein amino acids which can be toxic to non-adapted animals (including man) but, as these seeds previously been eaten by humans, in these particular species the compounds occur in quantities that do not appear to be harmful (Maslin et al. 1998). Cultivation and harvest of wattle seeds can provide edible oils and protein-rich press cake for both human and domestic animal consumption. There is always a good market for seed triglycerides. Fatty acids derived from these triglycerides are used commercially to make soaps, as precursors for plastics, for manufacture of lubricants, waterproofing substances, and a variety of other products. Highly unsaturated oils are traditionally used for paint and varnish formulation and are also considered highly desirable in human diets. Recently several saponic triterpene glycosides from Acacia victoriae have been examined for their ability to decrease tumor cell proliferation and to induce apoptosis (Haridas et al. 2001; Mujoo et al. 2001).

Of note are the copper levels in the leaves of some species which are abnormally high. Copper levels in tree species have not been reported to exceed 40 ppm (10 ppm in acacias). According to Underwood (1981), copper levels as low as 40 ppm can cause poisoning in sheep if levels of molybdenum and sulfur are low, but cattle are more tolerant of high copper concentrations.

Palatability of fodder

There are pronounced species differences in palatability within the genus Acacia (Everist 1969; Hall 1972). Meville (1947) in Western Australia noted that the acceptability of mulga for sheep increased with age of the tree and that this was associated with a decrease in the ether extract content of the leaves. In Queensland, the leaves from vigorous 'sappy' mulga trees are not readily eaten, and allowing lopped mulga foliage to lose volatile matter before feeding increases its acceptability. Little is known about the factors affecting palatability, although some observations suggest that volatile oils are responsible in the case of mulga. Graded quantities of fresh mulga (Acacia aneura) were fed with a low quality sorghum stubble diet. The mulga contained five times as much protein per kilogram of dry matter as the stubble. The mulga supplement only slightly increased rumen ammonia concentration indicating that the protein in mulga was not being broken down rapidly in the rumen. Mulga cannot be used to improve the quantity of nutrients obtained from a mature pasture, the leaves could still be used to extend the period of grazing on a grass pasture providing sufficient trees were available.

Intake of browse can sometimes be stimulated by, supplementation with nitrogen, sulfur and molasses (Niven and Entwistle 1983) and/or phosphorus (Ozanne et al. 1976) and intake of lignocellulosic material may also be increased by processing using physical, biological or chemical means (Wilkins 1982). The hypothesis that browses can be used as a supplement when grasses are mature and have a low nutritive value. There are no reliable indicators of intake for browse material from laboratory analyses alone even high digestibility and protein levels do not necessarily correlate with high intake.

Industrial utilisation potential

Furniture and paper industry

There has been increased market acceptance of the woods of acacia species following research on their properties and industrial utilisation. A. mangium and A. auriculiformis timbers make attractive furniture and are also suitable for interior construction work such as framing and flooring. They are less suitable for exterior use. The major tropical species have good potential for composite wood products including veneer and plywood, particle board, cement board and medium density ibreboard (Sudin et al. 1991; Razali Abdul 1993). Acacias used in rural development can be utilized for wood products, posts, poles, fuel wood, charcoal and non-wood products such as fodder, bee, forage, and tannins (Pinyopusarerk 1996; Razali Abdul 1993; Hsu-Ho 1993; Doran and Turnbull 1997). A. mangium in Sabah in Malaysia and A. meamsii in South Africa and Japan have been used for commercial pulping (Clark et al. 1994, Fang et al. l994a). Balodis (1991) highlighted the need to compare species on the basis of their pulpwood productivity, which is defined as the kilograms of pulp produced per cubic metre of wood. There is considerable variation in this measure between species and possibly between provenances. The possibility exists that the hybrid A. auriculiformis x A. mangium could be produced with acceptable form, good pulping characteristics and higher pulp productivity than either parent (Kha 1996). The pulp yield will be an important characteristic influencing species and clonal selection and acacia breeding, and will require greater attention by tree breeders. Pulping studies should be done on those species which show good silvicultural properties. Even if plantation material is not always available, older natural growth trees can provide a guide to pulping quality. It is becoming increasingly important to think holistically about forestry and to consider the role of people and economics in relation to technological developments. There will be greater involvement of small landowners in growing acacia wood for industrial enterprises and this will present new opportunities and challenges.

Attention needs to be turned to mechanical pulping studies and recently developed chemical processes such as the soda-AQ process in an attempt to extend the potential utilisation of Acacia species for a wider range of pulp and paper products. There is an increasing need for raw materials for use in newsprint manufacture. Hardwood pulps, especially hardwood mechanical pulps, can make a significant contribution to the range of pulps which can be used to make newsprint of various qualities. Mechanical pulp mills can be established on a smaller scale and at a lower cost per tonne than chemical pulp mills. This is of significance to developing countries considering the establishment of a pulp and paper industry. The soda-AQ process can produce high quality pulp without the environmentally unacceptable sulfur compound emissions which are present in some current commercial kraft pulping operations. Smaller scale operations are also a possibility with the soda-AQ process. Pulping studies using this process could therefore lead to the setting up of smaller, less capital-intensive, less polluting pulp mills, compared with commonly established kraft mills in developed countries.

Other specific properties affecting utilisation which need further investigation are (i) a study of the properties of black liquors resulting from the chemical pulping of acacias as a guide to processing characteristics in a pulp mill recovery system; and (ii) the determination of the effect of vessel-picking tendency of Acacia pulps on their use in the production of offset printing papers. It is suggested that developing countries undertake trial plantings of a range of Acacia species and those species which show promising growth performance should be tested for pulp quality as early as age 3-4 years. If a forestry department does not have access to pulp testing facilities, funds should be sought from overseas aid agencies, which assist developing countries, so that pulping studies can be carried out at an appropriate pulping research laboratory.

One of the main characteristics of Acacias selected for industrial plantations is their ability to grow fast on infertile sites. Some species show degrees of adaptability, for example A. auriculiformis will tolerate both highly acidic and alkaline sites. However, recent experience has shown that major benefits can be gained from careful attention to the application of fertilizer and selection of symbiotic microorganisms. The low potential and 'degraded' lands are the sites mainly being used for plantation forestry. As plantations enter their second and subsequent rotations, management regimes that assist nutrient cycling will assume greater importance.

Livelihood improvement Potential for Dry lands

Tree-based management of drylands has a number of advantages. It helps fight desertification, promotes conservation of biodiversity and assists farmers to better adapt to climate change (Lemenih and Teketay 2004). Gum- and resin producing species are adapted to extreme aridity, which makes them appropriate options for dryland conservation and combating desertification.

The economic incentive provided by the oleo-gum resins could have wider economic and ecological implications for households living in arid and semi-arid low lands. It diversifies the economy and potentially minimizes the risks associated with frequent crop and fodder failures as a result of recurring droughts. Generally, the pastoralist and agro-pastoralist economy in Liban and other parts of Ethiopia is not able to produce all the food families need for basic subsistence and food shortages are common even during the normal dry seasons (Farah, 1994). As a consequence, households are forced to consume purchased grains at relatively high prices, while selling their livestock at reduced prices since large amounts of livestock are supplied to markets during these dry seasons. One advantage associated with the vegetation resources that yield oleo-gum resins is their ability to produce gum and resins only during dry seasons when forage and grains are scarce (Chickamai and Gachathi, 1994). This could allow the people to be occupied in a meaningful economic activity to earn additional cash, thereby helping them to cope with the problems of high grain yields and falling livestock prices during dry seasons. Moreover, livestock production, which supplies the major needs of the pastoral families, heavily depends on the fodder provided from the same vegetation resources that supply the oleo-gum resin resources.

The importance of gum in the livelihood of the people inhabiting the gum belt is well known. More than four millions of people in the gum belt of Sudan are involved in gum tapping, harvesting, cleaning and trading of gum. Gum production is a pillar of family economy and considered as an income-generating source that requires only a low input of work after the rainy season (Gaafar 2005). Gum production in the Sudan has developed over generations in a tradition handed down from father to son. This long experience is not easily matched in other countries and in Sudan it is backed up by a well-established extension and research service. Some of the well-known gums of the world in terms of market capitalization nationally and internationally such as Karaya, Ghatti and katira are solely obtained from India. The important gums that have gained importance over the years are Gum Karaya (Sterculia urens), Gum Babul (Acacia arabica), Gum Tragacanth (Astragalus species), Gum Dhawara (Anogeissus latifolia), Gum Kumta (Acacia senegal), Gum Katira (Cochlospermum religiosum), Gum Khair (Acacia catechu), Gum Guggul (Commiphora mukul) and Gum Salai (Boswellia serrata). Gums are white gold for chenchus who earn a significant amount of their income from the produce. Each tribal community has a defined territory owned by it and recognized by the neighboring villagers. Even if the villagers leave that village for some reason it continues to be theirs and they exercise their right when they come back. Within this traditionally acknowledged territory, the individual families own the Karaya tree identified and cut by them. In some cases, where the trees are at a far distance from their habitation, a chenchu can migrate to the area where the trees are for 4-5 days at a stretch. The extraction from a tree is done only once in a given season. But in the areas where traditional rights are not clear on the trees, the harvesting is more unsustainable and the quality of gums suffers. The major issue in gum karaya market in India is that almost all the production is exported to other countries without much value addition. Only 5-8 percent of the total production stays back in the country. Among the major importers of gum karaya from India, France stood first; the importing quantity to France is consistently increasing for some time. The case is similar with the USA; rate of growth is slightly less. Another two importers Japan and UK, their importing quantities has shown a decreasing trend. The major issue in gum karaya market in India is that almost all the production is exported to other countries without much value addition. Only 5-8 percent of the total production stays back in the country. Among the major importers of gum karaya from India, France stood first; the importing quantity to France is consistently increasing for some time. The case is similar with the USA; rate of growth is slightly less. Another two importers Japan and UK, their importing quantities has shown a decreasing trend. Gum production communities suffer from the lack of regulatory infrastructure, sense of organized co-operative behavior as well as lack of trading information which is due to the inferior economic, social and demographic characteristics of these communities. Due to lack of finance and transportation facilities, small producers sell their production to the local traders at very low prices through Sheiling system (exchange of products with supplies of food, sugar, tee, coffee). The actual return to producer was reported to be 40% of the floor price for a particular season (Ibrahim 2002).

Total gum ghatti production in India is estimated to be around 900-1150Mt per year. Out of which almost 90 percent is exported to the United States of America and Europe, where it is refined, processed and value added. Because of its GRAS status (generally regarded as safe, by the Food and Drug Administration, U.S.A.) it is used in food and pharmaceutical industry. It is most often used as blend with gum arabic to reduce the cost. In India exudates gums available in retail market are mostly mixture of Arabic gum with gum ghatti or gum Karaya. In Indian market Gum Arabic is generally sold, in the form of tears (often mixed with other gums), but production of purified, spray -dried gum has also commenced in India. Gum Arabic produced in India is insufficient even for domestic consumption and more of it is imported from Sudan and Nigeria to meet country's requirements. The regions producing gum Arabic in India are the desert and arid region of Rajasthan and adjoining areas of MP, Gujarat, Haryana and Punjab. It has been reported that the gum yield from various acacia trees in their natural habitat in India is poor, particularly because many trees are very old and these are primarily being grown for timber, fire wood, seed and fodder, rather than for gum tapping. Currently over 70% of the world's supply of Gum Acacia is produced and exported by the Sudan. More than two different distinct species of acacia occur in the Sudan but the majority of the commercial gum comes from Acacia senegal and Acacia seyal. The other major supplying areas are Chad and Nigeria. Gum Acacia has also been sourced, although in small quantities, from Senegal, Mali, Mauritania, and Niger.

Land use sustainability

Land use sustainability is a challenge to the people living in dryland environments. Problems that commonly challenge these people include desertification, poverty and low levels of investment. Until recently, the traditional A.senegal-based agro forestry system was recognized and considered one of the most successful forms of natural forest management in the tropical drylands (Fries 1990), and regarded as sustainable in terms of its environmental, social and economic benefits (Ballal 1991). Traditionally, A. senegal tree is managed in a time succession with agricultural crops such as sorghum, pearl mille, groundnut, sesame and karkadeh. This agro forestry system allows a period of 10-15 years for restoring the soil fertility after a short period of arable cultivation (Ballal 2002). The cycle thus consists of a relatively short period of cultivation followed by a relatively long period of fallow. The bush fallow cycle starts by clearing an old gum garden (15-20 years old) for the cultivation of agricultural crops. Trees are cut at 10 cm from the ground surface, and stumps are left to initiate a vigorous coppice regrowth. The cleared area is cultivated for a period of 4-6 years, during which time the coppice shoot re-growth is removed to improve the establishment and growth of agricultural crops. However, when the soil fertility declines, crop growing ceases and the area is left as fallow under A. Senegal (Ballal 2002). The remaining trees are tapped for gum arabic until the age of 15-20 years, after which they are cleared again for crop cultivation. The bush-fallow system supports well the livelihoods of the local populations, because it is the major source of both cash, and subsistence. However the bush fallow system was disrupted and the traditional rotational fallow cultivation cycle has been dramatically shortened or completely abandoned (Awouda 1973). Consequently, the negative impact on the soil and water has been substantial, to the extent that commercial agriculture is also facing problems (Ballal 2002). Moreover, sustainable management of the gum gardens is threatened because of severe droughts and indiscriminate clearing of A. senegal stands for firewood and charcoal production for a short-term, albeit unsustainable, source of income (Ballal et al. 2005). Gum yields have decreased, however, because of biotic, physical, socioeconomic and institutional reasons. There is a need to look at this traditional dryland management from a more holistic perspective. Proper integration of gum yielding tree into the farming production system is needed. Therefore, an agroforestry-based approach must be considered where these multi-purpose trees/shrubs are integrated wherever possible with food crops or otherwise with livestock, to exploit the potential of the vegetation resources in the form of dryland forestry and agroforestry.

The problems of salinisation are sufficiently serious to require immediate remediation. Cultivation of trees on these wheat lands is one of the strategies being explored for accomplishing this effect, but many problems will be encountered. The arrangement and management of trees in relation to crops within an agroforestry practice have a bearing on microclimatic factors. A combination of A. senegal trees with crops affects negatively the total yield harvested from the land. A decrease in crop yield that results from competition between trees and crops can be tolerated, if the economic gain from gum production can be assumed to compensate for any loss in crop yield. There is a possible reduction in income for farmers unless suitable economic value can be found for these newly cultivated tree crops. Use of native flora will help to overcome problems that have arisen from use of introduced plants that have become invasive and weedy. Careful planting can restore a measure of the former biodiversity as well. Normal practice for revegetation is to choose drought-resistant, fast growing crops or fodder which can grow in nutrient deficient soils. Selected plants should be easy to establish, grow quickly, and have dense canopies and root systems. In certain areas, the main factor in preventing vegetation is acidity. Plants must be tolerant of metal contaminants for such sites (Mendez and Maier, 2008). The trees selected must be easily grown and possess a reasonable base of variation. Only those generating products such as fuels, petroleum replacements, wood products, major industrial solvents, major chemical precursors, fibres or foods are likely to be effective. To be useful, these bulk products must be of sufficient value to offset the costs of harvesting and transportation to sites where they can be processed efficiently. Nonetheless, commodities of intermediate demand and value such as gums, tannins and resins may supplement or complement low-cost bulk products. Smaller amounts of products of high value could round out this picture. Several examples like Sandalwood and Eucalyptus suggest that marketing chemical products from Acacia species can be successful. The scheme most likely to succeed will be a mosaic of exotic and native plants cultivated for wood products and bio-energy, with by-products based on tannins, gums and resins, wood waste for fuel, and plants used for essential oil production, all grown in combinations to suit local soil, slope and drainage, nearness to processing plants, centres of usage and points, and many other factors thrown together.

Potential in Folk Medicine

Several bioactive agents have been identified from the various species of acacia which includes androstene steroid, gallic acid, ellagic acid, isoquercitin, kaempferol, naringenin, rutin, lupane, niloticane, umbelliferone and catechin (Mutai et al., 2004; Eldeen et al., 2005; Singh et al., 2010). Among the Acacia species, Acacia nilotica (L.) subsp. indica occupies an imperative place in the indigenous system of medicine against various diseases. Different parts of A. nilotica have been used a remedy against variety of diseases in traditional medicine, in particular bark is used to treat diarrhoea, dysentery and leprosy, root is used in the treatment of tuberculosis and leaves are used to treat ulcers. Traditional healers of different regions in India particularly Chhattisgarh used Acacia species for treatment of various cancer types of mouth, bone and skin (Kalaivani and Mathew, 2010).

Gum arabic is a branched-chain, complex polysaccharide, either neutral or slightly acidic, found as mixed calcium, magnesium and potassium salt of a polysaccharidic acid. The backbone is composed of 1, 3-linked b-D-galactopyranosyl units. The side chains are composed of two to five 1, 3-linked b-D-galactopyranosyl units, joined to the main chain by 1, 6-linkages. Pharmacologically, Gum arabic has been claimed to act as an anti-oxidant, and to protect against experimental hepatic-, renal- and cardiac toxicities in rats.

In folk medicine, Gum arabic has been reported to be used internally for the treatment of inflammation of the intestinal mucosa, and externally to cover inflamed surfaces (Gamal eldin et al., 2003). Despite the fact that Gum Arabic is widely used as a vehicle for drugs in experimental physiological and pharmacological experiments, and is assumed to be an "inert" substance, some recent reports have claimed that it possesses anti-oxidant, nephroprotectant and other effects (Ali et al., 2008). Clinically, it has been tried in patients with chronic renal failure, and it was claimed that it helps reduce urea and creatinine plasma concentrations and reduces the need for dialysis from 3 to 2 times per week (Suliman et al., 2000). These findings are not universally accepted and their confirmation, validity, reliability and mode of action await further studies. Infusion of meals containing starch showed that a decrease in the digestion rate of starch in the upper small intestine accounted for part of the effect of viscosity on glycemic response, whereas the main effect of gum was apparently to slow gastric emptying.

Various mechanisms have been proposed to explain the hypocholesterolemic effect of Gum Arabic (Kelley and Tsai, 1978; Moundras et al., 1994). The mechanism most clearly implicated is related to increased fecal bile acid and neutral sterol excretion or a modification of lipid digestion and absorption. Dietary fibers are believed to either bind or sequester bile acids, diminishing their active reabsorption in the ileum and leading to their excretion in the feces.

It has been reported that Gum Arabic is not degraded in the stomach and small intestine, but undergoes complete fermentation within the cecum of rats (Walter et al., 1988), and humans (Phillips, 1998). Such fermentation promotes bacterial proliferation (Prevotella ruminicola-like bacterium) and the larger bacterial mass induces increased production of short chain fatty acids (acetate, propionate and butyrate) linked with enlargement of the cecum (May et al., 1994; Younes et al., 1995, Kishimoto et al., 2006). Propionate produced by bacterial fermentation from gum arabic is metabolized by the liver (Moundras et al., 1994), particularly as a gluconeogenic substrate. It is utilized at a faster rate than amino acids, thus reducing amino acids deamination and luminal ammonia generation. Bacterial growth within the large intestinal lumen requires a nitrogen source (Younes et al., 1995) and gum arabic fermentation provides the energy for bacteria to uptake ammonia as a nitrogen source. In addition, proprionate is also known to reduce ureogenesis from ammonium chloride in hepatocytes (Kishimoto et al., 2006). The decrease in luminal ammonia concentration may enhance diffusion of urea down its concentration gradient from the blood into the lumen. As such, nitrogen is trapped for elimination in the faeces.

Recently, it has been shown, using histopathological methods, that Gum Arabic has the ability to enhance remineralization (Onishi et al., 2008), probably by supporting remineralization activities and can prevent dental carries. This supporting role was ascribed to the rich content of Ca2+, Mg2+, and K+ salts of polysaccharides in Gum Arabic, and to the effect of the gum on the metabolism of Ca2+ and phosphate. No significant adverse or toxic actions have been associated with the use of Gum Arabic.

Biological Adaptations of Acacias to Survival and Climate change

Woody plants including Acacias have developed mechanisms to defend themselves against herbivores such as mammals and arthropods (Coley 1983). These mechanisms can have direct and indirect effects on the nutritive value of the plants. Characteristics such as toughness, fibrosity and phenolic compounds (tannins) typify persistent tree species as opposed to pioneers. As leaves mature and become physically tougher and less digestible, tannin concentration decreases (Coley 1983; Provenza and Maleehek 1983). Plants have evolved other strategies to deter herbivores which include unpleasant aromas, toxins and structures such as thorns and hairs. Plants also have to contend with fungi, particularly if they are under moisture stress, and to do this their leaves may contain high levels of phenolics (Van Soest 1982) and volatile oils. However, fungal responses to climatic factors are complex and uncertain because of interactions with tree host susceptibility and insect vectors. Some fungi-tree relationships are difficult to assess because important below ground interactions between fungi and tree roots are not well studied. Although the production of gums in plants is not well understood, these substances often accumulate in response to stress, injury, or bacterial, fungal or insect attack on the plant (Esau 1965). Degeneration of cells resulting in the formation of complex, variable gums occurs in a broad range of species. This process, called gummosis, results in the depletion of starch in cells and in many cases appears to involve breakdown of cell walls. Gums are usually associated with xylem cells and special structures called gum ducts (Esau 1965). Commonly they are exuded from the sites of injury into cracks and crevices in the bark or as irregular masses or 'tears' onto the surface of the trunk or branches. Besides defenses against herbivores, plants have adaptations to counteract dehydration including a tough cutin-covered outer layer. Acacia species hold a preferential place in agroforestry and land afforestation systems due their high resiliency to drought and grazing. A. hockii and A. gourmaensis may be suitable for narrow soil moisture with high exchangeable bases such as vertisol and cambisol. A. polyacantha most often occurred in soils with high available water and water holding capacity as water saturated soils with high exchangeable bases. A. dudgeonii is associated with important coarse fractions and low pH soils with low alteration processes such as shallow soils. With conversion to winter-growing annual plant agriculture, the capacity for summer extraction of deeply infiltrated water was removed; groundwater accumulated and mobilized the stored salts. As rising groundwater tables intersect the surface, usually on the broad valley floors, saline water is discharged and extensive degradation of land and streams occurs. Use of native flora will contribute to amelioration of salinisation problems and help to overcome problems that have arisen from use of introduced plants that have become invasive and weedy. Careful planting can restore a measure of the former biodiversity as well.

Abiotic environmental factors are a principal part of the environmental niche and therefore have a major impact on the distribution and performance of plant species. To improve the use of Acacia species in afforestation and agroforestry systems we need to study the environmental factors determining the ecological optimum and species growth performance. Among climatic factors, precipitation and temperature are the dominant causative factors for the species distribution. These two factors determine the water availability in the soil, atmospheric humidity and evapotranspiration, which regulate physiological processes of plants (gas exchange, transpiration, photosynthesis). There is, however, also the possibility, that species could change the environment in which they occur. Soil carbon and nitrogen were considered to stem from litter input and resulted from the effects of Acacia species on soils (Traoré et al., 2007; 2012).

Rising temperature increases the vapor pressure deficit, water loss through transpiration and stomatal closure in the case of isohydric species, or decreased margin of safety from hydraulic failure in the case of anisohydric species. Rising temperatures may impact the carbon storage of trees in a negative way because the rate of carbohydrate consumption maintaining cellular metabolism is strongly linked to temperature (Amthor, 2000). Photorespiration rates in C3 plants rises with temperature (Santosh kumari, 2010) as a result, the quantum yield (i.e., carbon gain per photon absorbed) is low. Experiments have shown that quantum yield drops with decreasing partial CO2 in C3 (Acacias species) plants, but is insensitive to CO2 changes in C4 plants (Ehleringer et al., 1997). Elevated CO2 will most likely mitigate some of the impacts of climate change by reducing water stress. Understanding how drought impacts on rates of dark respiration is crucial for predicting impacts of future climates on the productivity and performance of individual plants, as well as rates of carbon exchange over wide spatial and temporal scales. Future impacts on particular ecosystems include increased forest growth, alterations in competitive regimes between C3 and C4 grasses, increasing encroachment of woody shrubs into arid and semiarid rangelands, continued incursion of mangrove communities into freshwater wetlands, increasing frequency of coral bleaching, and establishment of woody species at increasingly higher elevations in the alpine zone (Huges, 2003).

Controlled experiments have consistently shown that under optimal growing conditions, plant growth is enhanced by elevated CO2: known as the 'CO2 fertilization effect'. The magnitude of this effect is, however, highly dependent on water and nutrient availability and under conditions of limiting nutrients such as N or P, enhanced growth at elevated CO2 may not occur at all. Acacia (C3) species have excellent water use efficiency when compared with other species and frequently dominate vegetation communities in arid and semi-arid regions ((Hansen, 1986, Specht and Specht, 1999). Acacia vegetation is subject to nutrient and/or water limitation, therefore, considerable uncertainty remains as to the magnitude of CO2 fertilization on the tree. A further difficulty for predicting the future response of vegetation is that elevated CO2 enhances water use efficiency in many plant species by reducing stomatal conductance. Enhanced CO2 may, therefore, mitigate some of the potential negative impacts of warmer, drier conditions in some areas (Farquhar 1997; Wullschleger et al. 2002). The Acacia species were found to be more robust to modest warming, with only one species having a biocimate predicted to disappear with a 0.5°C increase. However, the bioclimates of 59% of Acacia species would disappear with a 1°C increase (all species with a range less than 20 000 km2) and the rest suffer a decline in distribution of more than 75%. The bioclimates of all Acacia species were predicted to disappear with a 2°C warming. In general, species were predicted to track moving climate zones across the landscape because of soil constraints, but instead, to shrink to a smaller range within their current distribution (Chapman and Milne, 1998).

Warmer winter temperatures maintain significant physiological activity after the growth season, with tree respiration costs wasting stored carbohydrates (Damesin, 2003). Even though CO2 uptake can occur during mild winters and partially compensate for carbon loss during summer droughts (Holst et al., 2008), the annual C balance often remains in deficit under these conditions. Therefore under climatic warming scenarios, drought avoiding tree species may move closer to carbon starvation, and drought-tolerant species may come closer to hydraulic failure (McDowell et al., 2008). Research is also needed on how tree phenologies will respond to climate warming, because increasing winter temperatures may contribute to depletion of carbohydrate reserves relevant to carbon starvation thresholds. In addition, better knowledge is needed on within-species genetic variability and selection of trees related to drought and heat stress. There is little species-specific knowledge on regulation of xylem water potentials; almost no knowledge on the patterns or mechanisms of carbohydrate storage in response to drought and heat.

The degree to which trees regulate water loss during drought may explain patterns of carbohydrate (and resin) production and subsequent susceptibility to drought or biotic attack (McDowell et al., 2008; Zweifel and Zeugin, 2008; Zweifel et al., 2009). In addition to hydraulic failure through cavitation of water columns within the xylem and carbon starvation, low tissue water potentials during drought may constrain cell metabolism (thereby preventing the production and translocation of carbohydrates, resins, and other secondary metabolites necessary for plant defense against biotic attack (Würth et al., 2005; Ryan et al., 2006; McDowell et al., 2008; Sala and Hoch, 2009; Breshears et al., 2009; Adams et al., 2009). The observation that climate-induced tree mortality is happening not only in semi-arid regions but also in mesic forests suggests that the global rise in temperature may be a common driver (van Mantgem et al., 2009; Adams et al., 2009) in forest tree mortality.

Conclusion

The aptitude of the Acacia species to withstand drought and waterlogging, as shown by their abundance dominance in contrasting soil water regimes, makes them valuable afforestation species in the arid and semi arid regions under climate change. While climatic gradients appear to govern the distribution of Acacia woodlands at abroad regional scale, soil gradients are more important factors determining their floristic composition at small scale. The potential of soil organic carbon sequestration is finite in magnitude and duration. It is only a short-term strategy to mitigating anthropogenic enrichment of atmospheric CO2. The annual soil organic carbon (SOC) sequestration potential is only 0.9 F 0.3 Pg C/ year. The atmospheric concentration of CO2 at the observed rate of 1990 (3.2 Pg C/ year) will continue to increase at the rate of 2.0– 2.6 Pg C/year even with soil C sequestration. Thus, a long-term solution lies in developing alternatives to fossil fuel. Yet, SOC sequestration buys us time during which alternatives to fossil fuel are developed and implemented. It is a bridge to the future. It also leads to improvement in soil quality. Soil carbon sequestration by growing trees is something that we cannot afford to ignore. Legumes fix N2 for themselves normally releasing little N into the soil during their growth. However, some N is transferred from the decomposition of dead tissues such as leaves. cladodes or phyllodes, fruit, roots, and nodules. A multifunctionality and mixture of trees in a landscape needs to be ensured. Tree specialisation based on what is currently most profitable may not serve us well in the future. Although trees provide valuable environmental services, these functions are not generally the primary reason why farmers retain, manage and/or plant them. Rather, the impetus for cultivation is the value of the other products trees can provide, such as timber, food, medicines and energy, products with immediate and clearly apparent benefits to farmers' livelihoods. Many species are grown by farmers for a number of different uses and the particular use depends on specific household needs and the availability of markets for particular products. This in turn determines the specific traits needed in planting material and the particular ways in which trees are managed on farms. Rarely will a single tree 'ideotype' be available that fulfils a broad range of functions of a tree optimally, because such combinations of traits simply do not exist in nature and most trees are semi-domesticated at best. Unfortunately, in most developing countries, there are very few concerted efforts on tree improvement. This highlights the need for attention on selection and breeding that may result in significant productivity gains for specific functions.

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