Acacia *nilotica*: a multipurpose leguminous plant

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Abstract: *Acacia nilotica* is multipurpose nitrogen fixing tree legume that is widespread in Africa and Asia, and occurs in Australia. It is a complex species with nine subspecies, of which six are native to the African tropics and three others are native to the Indian subcontinent. It occurs from sea level to over 2000m and can withstand extremes of temperature (>50^{o}C) and air dryness but is frost sensitive when young. It is considered as a very important economic plant since early times as a source of tannins, gums, timber, fuel, fodder and medicine. The main advantage of this genus is its fast biological nitrogen fixation, ability to establish on nitrogen- deficient and drought prone soils and suitability for agro forestry systems and thus can be used in rehabilitation of dry lands. This article briefly reviews the botany, distribution, ecology, uses of the plant and its effect on soil and crops. This is an attempt to compile and document information on different aspect of *A. nilotica* and its potential use in land reclamation. [Nature and Science. 2009;7(4):11-19]. (ISSN: 1545-0740).

Key words: Legume, nitrogen-fixation, agroforestry, afforestation, nutrients.

Introduction

Acacia nilotica (L.) Willd. ex Del commonly known as babul, kikar or Indian gum Arabic tree, has been recognized worldwide as a multipurpose tree (National Academy of Sciences 1980). In Australia it is regarded as one of the worst weeds because of its invasiveness, potential for spread, and economic and environmental impacts. It is widely distributed throughout arid and semi-arid zones of the world. Presently about 20% of the total geographical area of India is wasteland. Growing demand for fuel, fodder, wood and food has extensively depleted or eliminated protective plant cover and exposed soils to processes of degradation resulting in partial to complete loss of soil productivity. Since nitrogen is generally deficient in such lands, there is a great need for the identification of suitable nitrogen fixing plants; those can thrive well during the process of stabilization and recovery of degraded sites. In such conditions *A. nilotica* can play an important role. It is a relatively fast growing, drought resistant multipurpose legume with the ability of biological nitrogen fixation. In addition, its strong tap root system (Toky and Bisht1992), long growing period of more than 300 days with four peaks of leaf flush (Beniwal et al 1992), it can intensively exploit soil column for nutrients and moisture. This species has high potential for nitrogen fixation(Toky et al 1994), and has been considered as one of the fast growing species of the wastelands, and agro forestry systems throughout India providing strong timber, fodder for goats and sheep, and high quality fuel wood apart from enriching the soil with nitrogen. In the present article information on various aspects of *A. nilotica* and its role in recovery of wastelands/degraded lands was reviewed.

Description

Acacia nilotica (family Leguminosae, subfamily Mimosoideae) grows to 15-18 m in height and 2-3 m in diameter. The bark is generally slaty green in young trees or nearly black in mature trees with deep longitudinal fissures exposing the inner grey-pinkish slash, exuding a reddish low quality gum. The leaves are bipinnate, pinnae 3-10 pairs, 1.3- 3.8 cm long, leaflets 10-20 pairs, and 2-5mm long. Thin, straight, light grey spines present in axillary pairs, usually 3-12 pairs, 5-7.5 cm long in young trees, and mature trees commonly without thorns. Flowers in globulous heads, 1.2-1.5 cm in diameter of a bright golden yellow colour, born either axillary or whorly on peduncles 2-3 cm long located at the end of branches (Fig. 1). Pods7-15 cm long, green and tomentose when immature and greenish black when mature, indehiscent, deeply constricted between the seed giving a necklace appearance (Fig. 2). Seeds 8-12 per pod, compressed, ovoid, dark brown shining with hard testa.

Growth pattern

A. nilotica germinates following rainfall in the wet season. Although 95% of seed become dead after two years, some seeds may still germinate up to 15 years after seed drop. Germination is aided when seeds are disturbed, e.g. by fire or by passing through the digestive system of animals. Seedlings grow rapidly near water but more slowly in open grasslands. Trees can flower and fruit two to three years after germination, and more quickly after high rainfall years. It flowers between March and June, with pods forming between July and December. Most leaf fall corresponds to this dry period between June and November. Seedpods drop from October to January (Table 1).

Distribution

A. nilotica is naturally widespread in the drier areas of Africa, from Senegal to Egypt and down to South Africa, and in Asia from Arabia eastward to India, Burma and Sri Lanka. The largest tracts are found in Sind. It is distributed throughout the greater part of India in forest areas, roadsides, farmlands, tank foreshores, agricultural fields, village grazing lands, wastelands, bunds, along the national highways and railway lines. Mostly it occurs as an isolated tree and rarely found in patches to a limited extent in forests. It has been widely planted on farms throughout the plains of the Indian subcontinent It is a species of Southern Tropical dry deciduous forests and Southern Tropical thorn forests as distinguished by Champion and Seth (1968).

Ecology

There is some evidence that *A. nilotica* is a weed in its native habitat e.g. South Africa (Holm et al 1979), but in other areas it is planted for forestry or reclamation of degraded land (Puri and Khybri 1975, Shetty 1979). The ecological implication of using *A. nilotica* as a browse source while maintaining in appropriate stocking rates is land degradation. It grows well in two types of soils i.e. riverian alluvial soil and black cotton soil. This species grow on saline, alkaline soils and those with calcareous pans. *A. nilotica* grows under climatic conditions ranging from sub-tropical to tropical. It can withstand extremes of temperature (> 50 ^{o} C) and conditions of drought however; adequate moisture is needed for full growth and development. It is frost tender when young and trees of all age classes are adversely affected by conditions of severe frost. It is fire tender and both seedlings and saplings are aversely affected by fire. The average annual rainfall varies from 250-1500 mm.

Economic importance

Acacias are established as very important economic plants since early times as source of tannins, gums, timber, fuel and fodder. They have significant pharmacological and toxicological effects In Africa and the Indian subcontinent; *A. nilotica* is extensively used as a browse, timber and firewood species (Gupta 1970, Mahgoub 1979, New 1980). The bark and seeds are used as a source of tannins(Shetty 1979, New 1980) The species is also used for medicinal purposes. Bark of *A. nilotica* has been used for treating hemorrhages, colds, diarrhea tuberculosis and leprosy while the roots have been used as an aphrodisiac and the flowers for treating syphilis lesions (New 1980). The gum of *A. nilotica* is sometimes used as a substitute for gum Arabic (obtained from *A. senegal*) although the quality is inferior (Gupta 1970). Indian Gum is sweeter in taste than that of the other varieties and is used in paints and medicine. The species is suitable for the production of paper and has similar pulping properties to a range of other tropical timbers (Nasroun 1979). The dark brown wood is strong, durable, nearly twice as hard as teak, very shock resistant and is used for construction, tool handles and carts. It has a high calorific value of 4950 kcal/kg, making excellent fuel wood and quality charcoal. It burns slow with little smoke when dry. It has a25% more shock resisting ability than teak. At the time of tree felling total wood production was estimated 167 Mg ha^{-1} that included 45 m^3 marketable timbers(Pandey and Sharma 2005). Survey of local timber market revealed that farmers fetch Rs 1000 from one tree (> 15 years) and Rs 30 to 90 thousand from 1 ha land, depending upon the stocking rate that makes the system economically viable. *Acacia nilotica* leaf is very digestible and has high levels of protein (Table 2). Micronutrients, with the exception of sodium, are adequate for animal requirements Leaves and pods contain 8% digestive protein (12.4% crude protein), 7.2 MJ/ kg energy and are rich in minerals and generally used for feeding sheep and goats in certain parts of India and also very popular with cattle. Pods are best fed dry as a supplement not as a green fodder. The bark contains high levels of tannin (12-20%) that is used for tanning leathers. Deseeded pods from ssp. *indica* have 18-27 tannin levels, whereas ssp. *nilotica* reached up to 50%. The relative tannin levels in *A. nilotica* from least to most are pods (5.4%), leaves (7.6%), bark (13.5%) and twigs (15.8%). The tannin also contributes to its medicinal use as a powerful astringent. It is also a powerful molluscicide and algaecide. Sub species *indica* and *cupressiformis* are commonly used in agroforestry. These subspecies makes an ideal windbreak surrounding fields. In India this species is used extensively on degraded saline/alkaline soils, growing on soils up to pH 9, with a soluble salt content below3%. It also grows well when irrigated with tannery effluent; and colonizes waste heaps from coalmines. Over 50, 000 hectares of the Indian Chambal ravines have been rehabilitated with *A. nilotica*.

Effect of *A. nilotica* on soil Characteristics

It was reported that the tree of *A. nilotica* improves soil fertility under its canopy by reducing proportion of sand with simultaneous increase in clay particles, mainly due to protection of soil from the impact of raindrops. Higher nutrient concentration under canopy compared to canopy gap (Table 3) is mainly a consequence of increased above and belowground organic matter input , nutrient cycling through leaf litter and protection of soil from erosion (Pandey et al.2000, Nair 1993 Palm 1995).The decrease in nutrient concentration towards the canopy edge compared to mid canopy position is mainly due to relatively low inputs of leaf litter as the canopy of *A. nilotica* is thin towards canopy edge(Pandey et al 1999).

A. nilotica is reported to be well nodulated with *Rhizobium* species (Dreyfus and Dommergues1981).This nodulation behaviour help in biological nitrogen fixation which help to meet the nitrogen requirement in nutrient-poor soils. In addition, this species form symbiotic associations with naturally occurring soil fungi called vesicular arbuscular mycorrhizae (VAM) (Kaushik and Mandal 2005). This association assists the roots to exploit more soil volume and to gain improved access to available nutrients especially phosphorus under stress and also makes the unavailable forms of nutrients into utilizable forms(Bowen 1973).

Effect of *A. nilotica* on crop yield

In the Central plain of Indian subcontinent *A.nilotica* grow naturally in the agricultural fields and forms an important agroforestry system (Pandey et al. 1999). It was reported that *A. nilotica* generally reduced crop yield under its canopy and this reduction varies with distance from the tree trunk (Pandey et al. 1999, Bargali et al.2004). In an experiment Bargali et al (2004) reported that gram yield increased with increasing the distance from the tree trunk and decreased with increasing the age of the tree (Fig. 3). In the Mitchell grasslands of northwest Queensland Australia, *A. nilotica* suppresses pasture production by 50% at 25-30% tree canopy cover or 2 m^2 basal area per hectare (Fig 4). It dramatically alters the ecological balance of grasslands and thereby threatens biodiversity. Pandey and Sharma (2005) reported that crop production depend upon distance from tree trunk and tree canopy size. Reduction in grain yield was maximum (30%) under the large tree canopy and lowest (12%) under the small tree canopy due to decreased availability of light by 44 to 62% under the canopy that resulted in slow photosynthetic rates and growth (Pandey et al.2000). Pandey et al (1999) suggested that the gradient of the incident light was the principal factor governing the gradient of grass biomass under developing canopies of all tree plantations. However, when the tree is felled after the completion of rotation cycle (>12 years) grain yield increased 126% for the first cropping season and 30 % for the fifth cropping season at 1 m distance from the tree stump and declined with distance (Pandey and Sharma 2005). These results suggest that the crop may exploit the greater amount of nutrients to increase productivity, if the tree canopy is open to facilitate greater light availability.

Allelopathic effect of *A. nilotica*

El-khawas and Shehata(2005) reported that the leaf leachates of *A. nilotica* inhibited the germination and growth of *Zea mays* and *Phaseolus vulgaris.* Duhan and Lakshinarayana (1995) found that the growth of *Cyamopsis tetragonoloba* and *Pennisetum* growing at distance of 1-2 and 7.5 m from tree of *A. nilotica* was inhibited. Velu et al (1999) reported that the *Acacia* spp. Have phytotoxic effects on the tree crops of legumes. These results suggested that the inhibitory effect of *A. nilotica* on seed germination and seedling growth is related to the presence of allelochemicals including tannins, flavonoids and phenolic acids. Moreover, the toxicity is caused due to synergistic effect rather than single one (Fag and Stewart 1994). According to Stratmann and Ryan (1997) and El- Khawas (2004) allelopathic effect of *Acacia* spp. induced the formation of stress proteins. These proteins are responsible for folding, assembling, translocation and degradation in a broad array of normal cellular processes such as improvement of plant growth, physiological and molecular characteristics (Wang et al. 2004). This allelopathic ability of *A. nilotica* may have the potential as herbicide and can be used in biological control of weeds (Li And Wang 1998).

Table 1. General growth pattern of *A. nilotica*.

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Flowering			■	■	■	■						
Pod formation							■	■	■	■	■	■
Seed drop	■											
Germination	■	■										
Leaf fall						■	■	■	■	■	■	

Table 2. Nutrient levels in *A. nilotica* leaf and fruit[30].

	Leaves	**Fruit (pod and seed)**
Parameter	Mean ± SD	Mean ± SD
Protein (%)	13.92 ± 2.53	12.30 ± 2.03
Fat (%)	6.63 ± 3.41	1.93 ± 1.14
NFE (%)	60.99 ± 3.41	63.68 ± 7.35
CF (%)	10.35 ± 2.85	15.36 ± 5.85
ADF (%)	20.38 ± 6.35	25.44 ± 4.16
Ash (%)	9.29 ± 2.95	5.26 ± 1.29
Tannin (%)	7.62 ± 1.00	5.45 ± 1.48
Lignin (%)	6.95 ± 2.17	-
P (%)	0.23 ± 0.22	0.26 ± 0.21
Ca (%)	2.53 ± 1.13	0.64 ± 0.19
Mg (%)	0.18 ± 0.08	0.13 ± 0.02
Na* (%)	<0.32	<0.01
K (%)	1.25 ± 0.79	1.28 ± 0.22
Si (%)	0.45 ± 0.47	0.24 ± 0.21
S (%)	0.26 ± 0.03	0.59 ± 0.11
Cl (%)	0.70 ± 0.26	0.36 ± 0.04
Cu (mg/kg)	-	6.43 ± 0.90
Zn (mg/kg)	25.63 ± 9.20	28.50 ± 9.76
Mn (mg/kg)	90.25 ± 19.00	2650 ± 0.71
Fe (mg/kg)	428 ± 205	100.00 ± 86.27
ME (mg/kg)	8.69 ± 1.09	10.19 ± 0.16
OMD (%)	69.9 ± 5.20	67.2

*Some values below limit of detection (0.05%)

NFE = Nitrogen free extract; ADF = Acid detergent fibre; CF= Crude fibre;

OMD= Organic matter digestibility; ME = Metabolisable energy

Table 3. Soil pH, Organic Carbon, Total N and Total P concentration under mid-canopy, canopy edge and open field of *Acacia nilotica* tree.

Soil depth (cm)	**Soil pH**			**Organic C (%)**			**Total N (%)**			**Total P (%)**		
	MC	CE	CG	MC	CE	CG	MC	CE	CG	MC	CE	CG
0-10	6.64	6.75	6.98	1.18	1.04	0.82	0.118	0.091	0.059	0.066	0.066	0.062
10-20	6.52	6.97	7.15	1.09	0.91	0.58	0.102	0.077	0.040	0.065	0.064	0.064
20-30	6.59	7.17	7.25	0.66	0.55	0.44	0.035	0.026	0.016	0.064	0.061	0.061
Mean	6.58	6.98	7.13	0.98	0.83	0.61	0.085	0.045	0.038	0.065	0.064	0.062

MC= Mid- canopy; CE = Canopy edge; CG = Canopy gap

Fig. 1. A twig of *A. nilotica* showing flowers.

Fig. 2. Pods of *A. nilotica.*

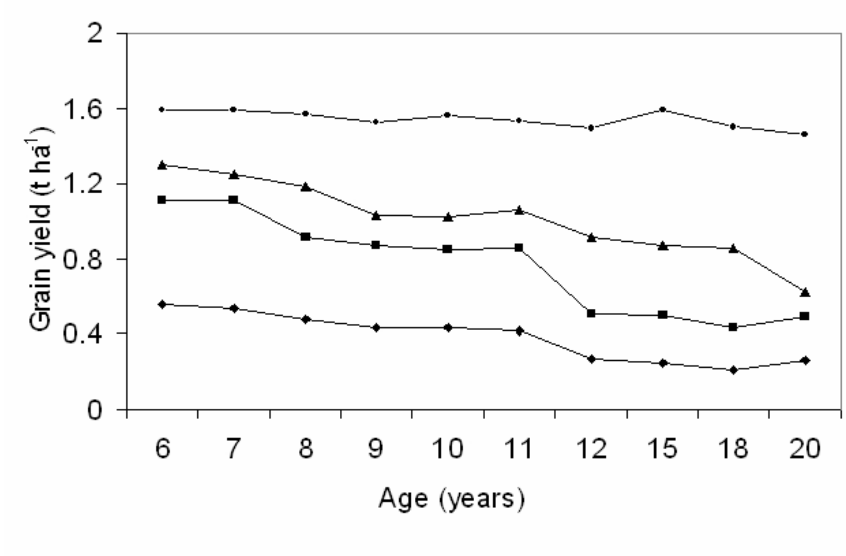

Fig. 3 Effect of *A. nilotica* on gram crop measured at different distances from tree. ◊--◊= 1m distance; ■-■= 3m distance; ▲-- ▲=5m distance and ●--● = open field

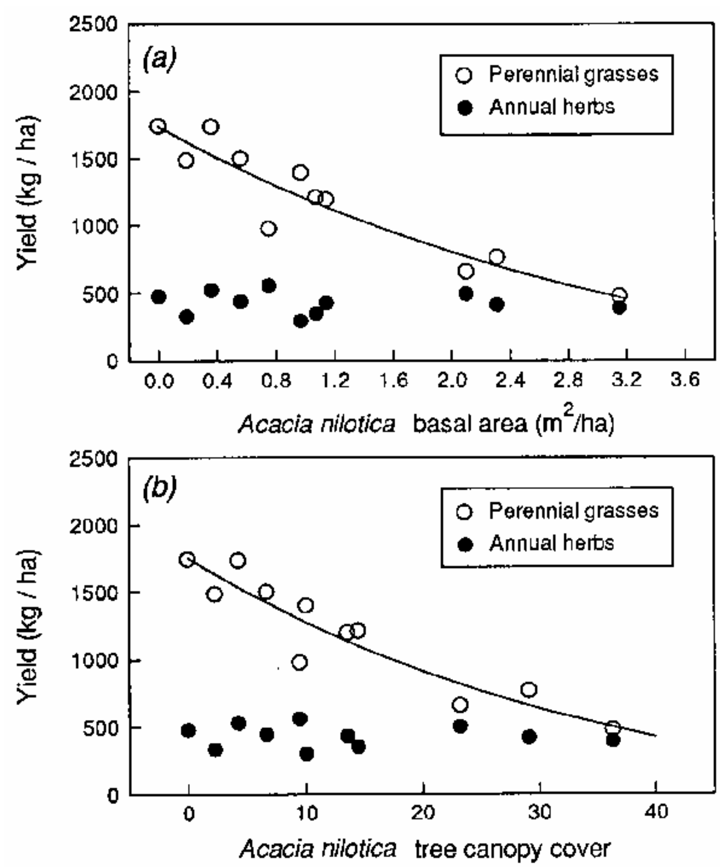

Fig 4. Effect of *A.nilotica* on pasture production (kg ha^{-1})

CONCLUSIONS

Being a drought resistance species *A. nilotica*; a multipurpose legume can be used for rehabilitation of dry lands. It increases soil organic carbon, total and available forms of N and P under its canopy so it can be used in soil amelioration. The chances of nitrogenous fertilizer use in various afforestation programmes are very bleak in the near future. The only alternative is to select such species that can meet their nitrogen requirements from soil as well as atmosphere. The nutrient generated by *A. nilotica* tree by biological nitrogen fixation, can be exploited within production system, either simultaneously as an intercropping plant or sequentially as in rotational fallow systems.

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