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Review Article

Anti-Nutritional Factors in Indian Leguminous Top Feeds: A Review on their Feeding Management

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Abstract

Anti-nutritional factors (ANF) in plants reduce the intake or nutrient utilization and determines the extent of using those plants as fodder for livestock. Compared to non-legume forages, leguminous fodder constitutes wide range of anti-nutritional factors. The nutrient composition of the tree legume fodders has been attracting the attention of many researchers to use them as a source of green fodder during drought and fodder scarcity. Although the leguminous top feeds are nutritious, few publications report various health related issues, productive losses and even deaths on consuming tree foliage at higher quantities. This necessitates the need to address the maximum quantity that can be fed to animals without any side effects and different processing methods capable of detoxifying the toxic factors present in them. Hence, this review dealt the information related to usage of fodder tree legumes in appropriate quantities depending on species and managemental practices for safe use.

Keywords: Anti-nutritional Factors, Fodder Tree Legumes, Productivity, Toxicity

Introduction

The conventional sources of green fodder are inadequate and diminishing gradually due to a variety of causes. A gap of 218.22 Mt of green fodder exists in India, necessitating suitable strategies and research level initiatives to strengthen the prevailing fodder resources (Earagariyanna *et al*., 2017). Investigating and scanning new feed resources is need of the hour. The leaf fodder from trees may provide a promising alternative for traditional green fodder. Promoting nutritionally superior top foliage may be a feasible approach to reduce fodder scarcity, especially during dry periods (Reddy *et al*., 2018). In developing countries like India, the fodder trees are cultivated mostly on unirrigated uplands, bunds, or marginal lands, thus sparing land for cultivation of food crops (Devendra, 1992). Besides, the role of tree foliages as top fodder will become more dominant with the changing environmental scenario.

Plants contain various types of chemical substances that are toxic to animals, which are primarily meant for defense against herbivores (Elghandour *et al*., 2018). Plants also secrete some substances that protect them from various bacterial fungal and insect attacks and helps in their survival (Reddy *et al*., 2020). Ingesting such type of plant material in large quantities results in impairment of health or productivity apart from exhibiting toxicity symptoms. In few cases, the acute toxicity may lead to the death of animals. Legume forages, often have physical defense by having thorns, fibrous foliages, spines and higher degree of lignifications, which protects them from defoliation. As a means of chemical defense, legume forages are also rich in tannins, cyanogens, saponins, lectins, alkaloids, glycosides, pheonolic compounds, enzyme inhibitors, and toxic aminoacids, which are not directly involved in the process of plant growth, but act as defense against bacterial fungal infections and insect attacks. These substances are known as anti-nutritional factors, which affect forage's nutritive value and animal health up on ingestion. Anti-nutritional factors or toxic factors are the compounds that affect the nutrient intake and feed efficiency on ingestion (Kumar, 1991). The effect of these toxins varies with species of animal ingesting the forages and the digestive mechanism of ingested compound. Generally non-ruminant species (pigs, poultry and horses) are more susceptible than ruminants (cattle, sheep, and goat), which posses the capacity of denaturizing most of the ANFs in the rumen. Further, the deleterious effect of toxins are judged by the degradation rate of rumen microbiome, subsequently influencing the growth and productivity of the animal.

Despite the presence of ANFs, legume fodder trees are an important source of green fodder in many developing countries such as India, Srilanka, Indonesia, Nigeria etc. The higher nutrition profile, especially CP content, along with draught resistant nature of these trees project them as excellent alternative fodders during extreme environmental conditions. In many nations, these fodder trees are successfully used as a sole source of fodder for raising small ruminants (Perera, 1992). Several research reports reveal that the addition of tree fodders to low quality feeds or agricultural byproducts improved the nutritive value of low-quality feeds. However, lack of awareness on the effective managemental techniques of fodder tree legumes is resulting in poor utilization of widely available nutrient resources. In this context, efforts are being made by animal nutritionists in coordination with plant breeders in identifying the specific toxic component of forages and various detoxifying methods. This paper reviews the information on ANFs or toxic compounds of legume tree fodders and feeding management to either reduce or remove their effect on animal health and productivity.

Legume Forages

Legume shrubs and trees have always played a significant role in feeding domestic animals. These trees and shrubs are increasingly recognized as important components of animal feeding, particularly as suppliers of protein in adverse environmental conditions. Apart from their potential role in animal feeding, legume trees and shrubs could also help in maintaining soil fertility by means of nitrogen fixation. Although legume forages are important sources of protein for livestock, they probably contain a great variety of toxic constituents than non-legume forages. The utility of these protein rich leaves, pods and edible twigs of legume shrubs and trees as animal feed is limited by the presence of ANF (Mcsweeney *et al.,* 2002). The toxicity of a plant and its deleterious effect on animal health depends on a complex relationship of dose absorption, detoxification, and excretion of toxic principles. Different legume tree fodders along with their ANFS and detoxifying methods are discussed here under. The anti-nutritional factors in legume tree tops, their effects, level of inclusion, and feeding management are presented in Table 1. The traditional detoxifying mechanisms of ANF are shown in Figure 1.

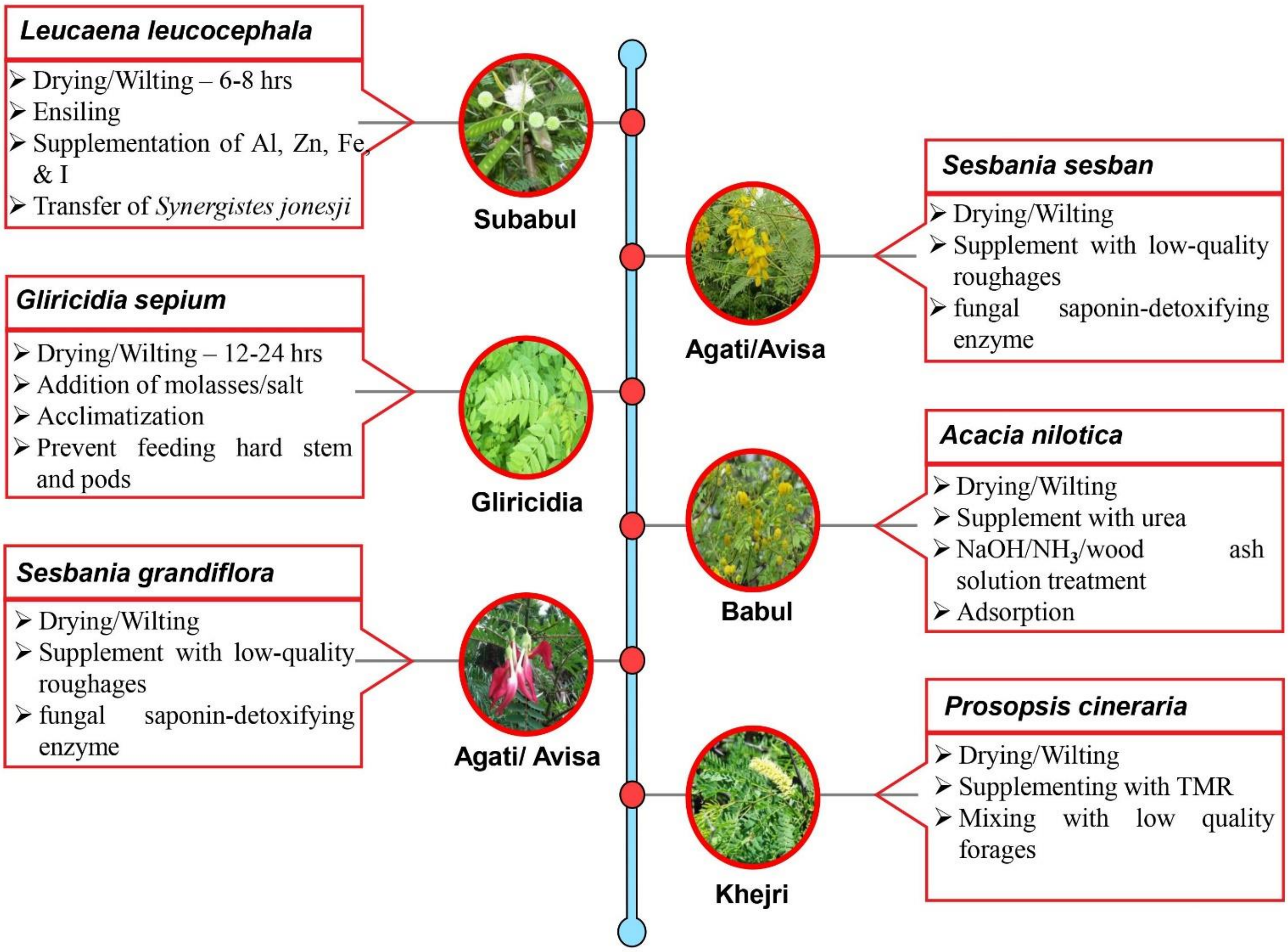

Figure 1: Traditional detoxifying mechanisms of ANF

***Leucaena Leucocephala* (Subabul)**

Leucaena is a rapidly growing, vigorous, drought tolerant, palatable, and high yielding tropical or subtropical legume, enriched with protein (25-35% CP) and other nutritional components. It is considered as a miracle tree for its protein rich foliage (20-30%), fast growing habit, drought tolerance, fuel capacity, and ability to use as organic nitrogenous fertilizers and charcoal gum. Due to high yield of good quality fodder and other qualities, *Leucaena* was introduced in several states of India and favourable results were reported earlier (Ghosh and Bandyopadhyay, 2007). Extensive studies were carried out on various aspects of *L. leucocephala* at Bharatiya Agro Industries Foundation (BAIF), Hissar Agriculture University (HAU), Indian Grassland and Fodder Research Institute (IGFRI), National Dairy Research Institute (NDRI), and Indian Veterinary Research Institute (IVRI).

Animals can be allowed to browse on this plant when the branches are tender as the nutritive value of the plant material may diminish due to lignification. For using this as fodder, branches should be cut, when the plant is 3 to 4 feet height. The protein content of Leucaena varies from 19-31% (Ghosh and Bandyopadhyay, 2007). Garcia *et al*. (1996) reported that *Leucaena* leaf meal contains 42% RDP and 48% UDP with amino acid values comparable to that of soybean meal and fishmeal, excluding sulphur amino acids. In spite of excellent source of nutrients, leaves and pods of *Leucaena* contains a number of toxic constituents, which may severely limit their utilization in livestock. The poor nutritive value of *Leucaena* arises principally from its toxic amino acid, mimosine and its degradation products. The mimosine content varies with plant part, season, and maturity status (Kumar, 1991) and varies from 1.02% to 5.56% of DM in leaf meal and hay. The concentration of mimosine in the growing tips of the leaves and pods may reach up to 12% and 5%, respectively (Ghosh and Bandyopadhyay, 2007).

Table 1: The toxic principles, recommended level of inclusion, and feeding management of various Indian leguminous top feeds

Fodder	Common names	CP%	Toxic principle	Toxic effects	Toxicity symptoms	Recommended level of inclusion	Feeding management
Leucaena leucocephala	Subabul	25-30%	-Mimosine/ leucinol	-Interferes with catalytic action of Pyridoxine.	-Poor growth, loss of hair and wool	-5-10% in non-ruminant diet.	-Drying/wilting the fodder at least for 6-8 hrs in shade before feeding.
			-Condensed tannins	-Reduced absorption of Calcium and Zinc.	-Hoof abnormalities, -Lameness, mouth, and oesophageal lesions, and -Development of goiter.	-Up to 30% of diet in cattle, buffalo, and sheep.	-Ensiling reduces 90% of mimosine.
			-Flavanol glycosides	-In Rumen, mimosine produces 3,4-dihydroxypyridone (3,4-DHP), a potent goitrogen.	-Acute toxicity may lead to death.	-In goats up to 50% of total green fodder.	- Supplementation of metal ions like Aluminium, Zinc, iron, and Iodine. -Transfer rumen degrading bacteria (*Synergistes jonesji*) from adapted cattle to normal cattle
Gliricidia sepium	-Quick stick	20-30%	-Pinitol	-Reduced digestibility of nutrients due to presence of tannins.	-Reduced intake due to low palatability.	-Up to 30% in cattle.	-Mixing with non-legume fodders and feeding.
	-Mexican lilac		-Tannins	-Toxicity symptoms could be due to the conversion of coumarin to dicumarol by the rumen bacteria at higher level of consumption.	- Reduced growth rate.	-75% of total green fodder for sheep.	-Wilting *Gliricidia* leaves for 12-24 h before feeding wilting.
	- Mother of cocoa		-Canavanine" (2-amino-4-guanidooxy-butyric acid)	-Coumarins act as precursors for phytoestrogens, which affects female reproductive system in ruminants.	-Infertility, abortions, and other reproductive problems in sheep.	-100% as green fodder for goats.	-Addition of molasses or salt.
			-Coumarins (precursors of phyto-oestrogens)				-Acclimatization by prolonged exposure to reduce palatability problems. -Feeding of tender wilted leaves without hard stem and pods.
a) *Sesbania sesban*	-Avisaagathi	20-36%	-Saponins	-Effects growth of young calves.	-Reduced growth rates	-15% in diets of rabbits.	-Feed as a protein supplement to low quality roughages such as crop residues or dried grasses.
	-Agase.		-Cyanidins (condensed tannin precursors) in *S. grandiflora*.	-Methyl esters exhibits haemolytic activity in young animals.	-Abortions	-20% in ruminant diets.	-Wilting or drying before feeding.
b) *Sesbania grandiflora*	-Vegetable humming bird. -River hemp.		-Methyl Oleanolate in flowers.	-Seminiferous tubular degeneration,	-Anoestrum		
			-Canavanine in leaves	-Changes in scrotal circumference.	-Reduced libido in males.		
				-Interstitial fibrosis in rams.	-Anaemia.		
				-Lowered oestrus period, abortions,	-Bloat.		

				and death of pregnant ewes.			
Acacia nilotica	-Babul,	15-20%	Hydrolizab-le tannins.	-Decreased protein digestion and absorption.	-Reduced growth rates.	-20% in ruminant diets	-Drying under sun.
	-Thorn		-Condensed tannins and other phenolic compounds, which imparts bitter taste	-Disturbance in rumen microflora.	-Reduced digestibilities of nutrients.		-Supplementation of readily available nitrogen source.
	-Mimosa,						-Treatment with NaOH or liquid ammonia.
	-Thorn						-Treatment of fodder with wood ash solution.
	-Arabica						
	-Tumma						
Prosopis cineraria	-Khejri.	11-19%	-Hydroliza-ble tannins.	Interfere with protein digestion and also with microbial protein synthesis and organic matter digestibilities.	- Reduced growth rate	-Upto 50% in concentrate of sheep.	-Sun drying the leaves and pods.
	-Jammi.		-Condensed tannins		- Reduced wool production	-75% in concentrate feed of goats.	-Mixing and feeding with low quality forages.
					- Reduction in nutrient digestibilities		-Leaf meal inclusion in TMR.

Mimosine also known as "leucinol" is more toxic to non-ruminants and feeding of *Leucaena* meal above 5 % of the diet for swine, poultry, and rabbits generally results in poor animal performance. Mimosine exerts its toxic effects by acting as an amino acid antagonist or forming complexes with pyridoxal phosphate, ultimately disrupting the catalytic action of B6-containing enzymes such as trans-aminases. The toxin may even form complexes with metals such as zinc and calcium making them unavailable to the animal (Kumar, 1991). Horses appear to be most susceptible and lose their hair, especially the long hair of the mane and tail. In severe cases, there is patchy loss of hair above and below the hocks, knees, flanks, and on neck. Continuous feeding of *Leucaena* to ruminants above the recommended levels results in development of toxic signs like poor growth, loss of hair and wool, hoof abnormalities, lameness, mouth and oesophageal lesions, and goitre. Mimosine plus an enzyme in plant tissue produces 3,4-dihydroxypyridone (3,4-DHP), a potent goitrogen, (Gupta and Atreja, 1998), which on mastication yields 2,3-DHP through the action of rumen flora. Apart from mimosine, 3,4-DHP and 2,3-DHP also exhibit toxic symptoms. Hill (2003) proposed safe daily intakes of mimosine as 0.18 g/kg BW for cattle, 0.14 g/kg BW for sheep, and 0.18 g/kg BW for goats.

Mimosine and its metabolites are the main limiting factors for the utilization of *leuceanea* as animal feed. Restricting the levels below 5-10% of the ration of monogastrics in dried leaf meal form may help in reducing its adverse effects (Angthong *et al.*, 2007). Uday *et al.* (2018) reported positive results of feeding *leucaena* leaves to growing kids upto 30% of total diet after treatment with moist heat. The proportion of *leucaena* leaves should not be fed higher than 30% total green forages offered to cattle, buffaloes, and sheep, while the incorporation levels may as high as 50% of green fodder in goats (Rajendran *et al.*, 2001), which are comparatively resistant to mimosine toxicity. Studies showed higher degradation rate for buffaloes compared to cattle (Ram, 1992). Drying the fodder at least for 6-8 hrs. in shade helps in reducing the mimosine content of the fodder. Hence, the practice of cutting fodder during cool hours of morning and feeding at evening times should be practiced. Supplementation of metal ions like Al, Zn, Fe and Iodine on leaucaena-based diet improved the DM intake (Hue and Amien, 1989; Rajendran *et al.*, 2001; Pattanaik *et al.*, 2000). Ensiling of *leucaena* leaves is the best method for preservation and mimosine reduction to as low as 90% (Anthong *et al.*, 2007). Another way to detoxify mimosine is transferring rumen-degrading bacteria (*Synergistes jonesji*) from adapted cattle to normal cattle population. Development of mimosinase enzyme cultures from rumen and soil bacteria through RDNA technology and utilization of these cultures along with subabul leaf meal helps the negative effects of mimosine on animal health (Tawata *et al.*, 2008**).** Domenguez-Bello and Stewart (1991) found a clostridium strain that degraded mimosine, 3,4-DHP, and 2,3-DHP to normal metabolites of rumen fermentation in sheep. The authors found a degradation rate of mimosine at 88-89% on inoculating the clostridium strains through *in vitro* batch cultures.

Gliricidia Sepium

Gliricidia is a perennial medium sized (2-15m height) legume fodder tree and yields 9-10 tons/ha (DMB). *Gliricidia* *sepium* is believed to be the most widely cultivated multipurpose tree after *Leucaena leucocephala*. Apart from the fodder source, *Gliricidia* could be used as bee forage, fuelwood, construction poles, crop supports, and green manure (Simons and Stewart, 2007). A distinct advantage of *Gliricidia* is its ability to root from cuttings or stakes with high attendant survival reflected by one of its common names, 'quick stick'. The benefit of using long stakes is that they are not grazed out and compete better with other vegetation relative to seedlings. In many cases, *Gliricidia* will yield as much more biomass than *L. leucocephala*. One of the reasons for its recent popularity is its complete resistance to the defoliating psyllid (*Heteropsylla cubana*), which has destroyed *L. leucocephala* in many parts of the tropics.

There is varying opinion about the nutritive value of *Gliricidia*. Leaves of *Gliricidia* have a high feeding value, with 20-30% CP, 15% of CF, and *in vitro* DM digestibility of 60-65% (Adejumo and Ademosun, 1985). Carew (1983) has suggested that *Gliricidia* may also be used as a sole protein source for ruminants. Perera *et al.* (1991) reported high ruminal degradability of *Gliricidia* relative to other multipurpose tree forages. Indeed, *Gliricidia* is commonly used as sole feed source to domestic goats in Sri Lanka during the dry season (Perera, 1992). Despite the tree's popularity as a high quality forage, the palatability of the tree fodder is low because of higher levels of tannins. The low palatability and initial reluctance of animals in consuming gliricidia leaves could be related to the strong odour of its leaves (Carew, 19983). However, no long-term effects were noticed on the productivity of sheep and cattle on feeding *Gliricidia* leaves at 30% of their diet (Chadhokar, 1982). The tannin content of *Gliricidia* leaves does not appear to interfere with plant protein availability but may be one of the factors affecting palatability and reducing the growth rate of livestock. Drying the leaves before feeding removed all extractable tannins and the *in vivo* trials showed higher DM intake, N digestibility and N balance in sheep fed with dried leaves (Ahn *et al.,*1989). Even though drying removes tannins and improves the nutritive value, few factors, which are responsible for poor palatability, could not be removed. The factors affecting palatability of *Gliricidia* in ruminants are probably the same as those that depress digestibility and growth in pigs, rabbits, and chickens (Raharjo *et al.,* 1987). Sotelo *et al.* (1986) have reported a thermostable toxin in *Gliricidia* seeds, which killed mice within one week of feeding. These authors isolated a non-protein amino acid, canavanine (2-amino-4-guanidooxy-butyric acid) from *Gliricidia* seeds, which may be associated with the toxicity of *Gliricidia* in non-ruminants. Leaves are also reported to be toxic to horses (Ecocrop, 2009). The toxicity in ruminants on consuming the foliage of Gliricidia at higher level could be due to the conversion of coumarin to dicumarol by the rumen bacteria during fermentation (Cook *et al.,* 2005).

Gliricidia bark and seeds are reported to be used as rat poison in some countries (Sotelo *et al.,* 1986) suggesting that a toxic principle is present. Coumarins have been found in *Gliricidia* leaves, which are precursors of phyto-oestrogens and cause infertility, abortions, and other reproductive problems in sheep (Griffiths, 1962). However, Chadhokar (1982) fed diets containing 75% *Gliricidia* to pregnant sheep and found higher birth weights and lower still births of lambs. Supplementation with *Gliricidia*, at 22.5 g DM/Kg $W^{0.75}$, to basal diets such as panicum hay, rice straw, sorghum Stover, and Rhodes grass increased daily weight gain, DM intake, and digestibility of nutrients in goats (Abdul Razak *et al.,* 2006, Srinivasulu *et al.,* 1999). Feeding the *Gliricidia* leaf meal up to 10% in tilapia fish diets resulted in better performance (Nanji *et al.,* 2010).

The palatability problems of *Gliricidia* is mostly attributed to the volatile compounds present on leaf surfaces., which could be reduced by wilting, molasses or salt supplementation, and acclimatization through prolonged feeding. Wilting *Gliricidia* leaves for 12-24 h before feeding is found to increase intake markedly and is therefore recommended during low palatability cases (Hawkins *et al.,* 1990). In non-ruminants, feeding of tender wilted leaves without hard stem and pods can minimize the toxic effects of *Gliricidia*. Despite the palatability problems in ruminants, the promising nutritive value of *Gliricidia* as a source of forage led to continuous studies in livestock.

Sesbania

Sesbania is used as forage and green manure. Two species of *Sesbania* are potential useful forage sources viz., the slower-growing tree *S. grandiflora* and the rapidly growing short-lived species *S. sesban*, which grows to a height of 8 meters. *S. grandiflora* leaves and pods are reported to be palatable and non-toxic for cattle. *S. sesban* yields 15-20 tons of DM per ha/year under favorable conditions. In soilage system, *Sesbania* can be cut at 1-2 mt height with a cutting frequency of 4-6 times a year. Sesbania is relatively well suited for highland areas when compared to *Gliricidia* and *Leucaena* (Mekoya *et al.,* 2009). These plants are able to fix atmospheric nitrogen and grow in water lodged, saline, alkaline, and highly cultivated soils (Shahjalal and Topps, 2000).

Sesbania foliage is rich in protein. The leaf meal contains about 20-36% of CP and upto 30% NDF. Dry matter digestibility of *Sesbania* species is superior to that of most of other tree fodders. In this regard, farmers of Indonesia prefer *Sesbania* leaves to *leucaenea* because of its palatability and nutritive value (Gutteridge and Shelton, 1994). They also reported improved body weight gains (0.7 Kg/head/day) in heifers fed with *S. sesban* for 15 months. Eys *et al.* (1986) and Akkasaeng *et al.* (1989) found higher *in-vitro* digestibilities of *sesbania* species than other tree fodders with the digestibility values ranging from 66-75%. The DM digestibility of sesbania in goats was found to be 71.4% (Singh *et al.,* 1980). Ahn *et al.* (1989) reported that the *in sacco* DM and nitrogen digestibility of dried foliage of *S. sesban* was 90.7% and 96.7%, respectively.

In spite of higher *in vitro* digestibilities and better apparent nutrient status than many other browse trees, the lower live weight gains achieved in feeding experiments on feeding *sesbania* leaves at a higher rate may be associated with anti-nutritive factors in the *Sesbania* forage (Reed *et al.,* 2000). It is one of the less tanniferous forage tree legumes (Kaitho *et al.,* 1998), but contains appreciable quantities of saponins (>10%) (Heuze *et al.,* 2012), which may decrease the ruminal methane production. A major difference between the species is that *S. grandiflora* contains condensed tannin precursors (cyanidins) in leaves, while no tannin could be detected in *S. sesban.* However, both species contain saponins that are potentially toxic to non-ruminants (Mekoya *et al.*, 2009). The methyl ester of oleanolic acid has been isolated from the flowers of *S. grandiflora* and shown to have hemolytic effects on sheep and human erythrocytes (Kalyanaguranathan *et al.,* 1985). Sesbania also contains canavanine, which causes arginine deprivation. Inclusion of *S. sesban* leaf meal in poultry diets at 10% of diet proved to be fatal to young chicks, and that the provision of either cholesterol or sitosterol with the diet may improve the survival (Shquier *et al.,* 1989). These authors reported that the leaves contain a saponin-like toxin and a heat labile factor. It was clear from these studies that both *Sesbania* species contain a number of toxins with specific activity against a variety of organisms. Olvera *et al.* (1988) found poor growth and high mortality in *Tilapia fingerlings* on including *S. grandiflora* leaf meal at either 10% or 35% of the diet. In sheep and goat, feeding Sesbania at higher levels (28.9%) resulted in deleterious effects on growth and reproduction of male and females (Mekoya *et al.,* 2009). They observed changes in scrotal circumference, interstitial fibrosis, seminiferous tubular degeneration, lowered estrus period, abortions, and mortality of pregnant ewes.

In a study, Tessema *et al.* (2004) observed increased dry matter (DM), organic matter (OM), crude protein (CP), crude fiber (CF), and neutral detergent fibre (NDF) degradabilities on supplementing the Napier grass with Sesbania at different proportions viz. 0, 10, 15, 20, 25 percent of dry matter. Sesbania foliage has improved the N retention in cattle, sheep, and goat compared to other forage tree legumes such as Tithonia and Calliandra (Wambui *et al.*, 2006). In rabbit diets, Sesbania leaves could be included up to 15% without any harmful effects on performance (Ghazalah *et al.*, 1998). It appears that the most economically efficient and safest use of perennial *Sesbania* forage for ruminants is as a protein supplement to low quality roughages such as crop residues or dried grasses. This dilutes the effects of anti-nutritive factors and greatly improves the utilization of the roughages. According to Gutteridge and Shelton (1994), 15 to 20% of *Sesbania* leaves can be included in the ruminants' diets without causing adverse effects. The use of the perennial *Sesbania* species should be restricted to young ruminants because of the deleterious effects often observed while using the leaf meal as feed sources for monogastrics. However, feeding adult ruminants with higher proportion of Sesbania foliage, for longer periods, may cause adverse effects on productivity and health. Research conducted so far is not sufficient regarding the anti-nutritive factors present in *Sesbania*, and there is a need for cost effective managemental practices to reduce the effect of saponins by various biological and physico-chemical methods.

Acacia Nilotica (Babul)

Acacia is a medium sized thorny nearly evergreen tree that can reach a height of 20-25 mts height. It may even remain as a shrub in poor growing soil conditions (Ecocrop, 2014). In Indian subcontinent, Acacia is extensively used for timber, fuel, fodder, food, honey, gum, dye and shade purpose. It influences the environment through soil reclamation, soil enrichment, protection against fire and wind, and as a heaven for biodiversity. It is extensively used in ethno-medicine (Cook *et al.*, 2005). Acacia serves as a very important fodder source in dry and fodder scarce areas. The foliage and the pods dropped can be a fundamental source of nutrients in periods of feed scarcity (Gutteridge and Shelton, 1994). The small ruminants, particularly goats, browse leaves and pods of Acacia. The rural Indian farmers often collects the acacia pods and feed them to livestock.

The nutritive value of acacia is difficult to evaluate as the parts browsed by the animals include various parts like leaves, petioles, twigs, shoots, flowers, and pods at various stages of maturity, which varies with season. Fiber and tannin contents are the most variable components of acacia foliage and pods. The protein content of leaves and pods varies from 10-20% (Bakshi and Wadhwa, 2004) while the fiber content ranges from 17-30% (Agang *et al.*, 1998; Azim *et al.*, 2011). Seeds of Acacia are comparatively rich in protein and fiber (20% CP, 30% CF). According to the *in vitro* studies of Barbind *et al.* (1994), the DM digestibility coefficients of acacia foliage was 55%. However, the *in sacco* degradability studies by Cheema *et al.* (2011) revealed that the DM Digestibility of acacia foliage may be as high as 66%. Inclusion of acacia foliage in diets of goats at 20% level decreased N absorption and retention and negatively affected the rumen microflora (Mokoboki *et al.*, 2011). The soluble phenolic compounds are high in acacia pods and the levels of extractable and condensed tannins concentration in the pods may reach up to 25% and 5%, respectively (Rubanza *et al.*, 2005). While screening various fodder trees for tannins, Bakshi and Wadhwa (2004) reported that acacia leaves contain highest concentration of hydrolysable tannins (14.6%).

Large amounts of condensed tannins are responsible for higher phenolic compounds in the pods, which further reduce the feeding value and palatability by imparting bitter taste (Mlambo *et al.*, 2008). The palatability studies of various tree fodders revealed a comparable palatability index of Acacia with Sesbania, although the former contains tannins at higher amounts (Ebong, 1995). Several research works are being conducted to abate the adverse effects of tannins and to ensure the easy availability of cheap and good quality protein along with alleviating negative effects of acacia tree fodder. Sun drying is the most convenient method to reduce the tannin content. Supplementation of readily available nitrogen sources to dilute the effect of tannin activity is another considerable method (Rubanza *et al.*, 2005). Sikosana (2006) suggested alkaline NaOH or NH_3 treatment as an efficient detanning method; however, these treatments are unsafe for animal health. Treatment with wood ash solution (mild alkali) may be helpful in reducing the concentration of soluble tannins from crushed pods.

***Prosopis Cineraria* (Khejri, Jammi)**

Prosopis cineraria, commonly known as *Khejri or jammi*, is an important species for arid zone agroforestry in India (Arya *et al.*,1995) and is declared as the state tree of Rajasthan and Telangana states. The distribution of this top fodder tree is seen in the Great Indian Desert Thar, and in central Pakistan, but smaller populations occur in Iran, Afghanistan, and Arabian Peninsula (Islam *et al.*, 2019). The foliage of *Prosopsis cineraria* was investigated for various phytochemical constituents such as alkaloids, carbohydrates, steroids, proteins, phenols, tannins, flavonoids, glycosides, and saponins as per the Indian Pharmacopoeia. Hence, the tree is most popularly known for its medicinal value as antibacterial, antifungal, anti-emetic, and antioxidant activity and its leaves, seeds, flowers and bark has been extensively used in ethno medicinal preparations (Napar *et al.*, 2012). Tender pods are also used for human consumption. Leaves and pods are known for their protein value (CP, 11-19%) and are readily relished by small ruminants. The branches of *P. cineraria* are frequently lopped during winter, and the dried are used during fodder scarce seasons (Arya *et al.*, 1995). CSWRI (Central sheep and wool research institute) carried out extensive research on the nutritive value, level of incorporation and ant nutritional factors of *P. cineraria*. The content of CP, NDF, ADF, and ADL varies from 10.7% to 15.9%, 34.9 % to 56.7%, 19.8% to 49.7%, and 18.9%-32%, respectively (Raghavendra *et al.*, 2007; Dutta *et al*., 1999; Arya *et al.*, 1995). In a study, Rani *et al*. (2013) analyzed the chemical composition of leaves and pods and revealed that the CP, EE, CF, NFE, TA, Ca, and P content of leaves were 11.2%, 2.9%, 17.5%, 43.5%, 8.1%, 2.1%, and 0.4%, respectively. Further, the contents of CP, EE, CF, total carbohydrates, TA, Ca, and P of prosopsis pods were 18%, 2%, 26%, 56%, 8.1%, 0.4%, 0.2%, respectively.

The DCP and TDN values of dried leaves of *P. Cineraraia* were 4.6% and 31.6% for goats and 1.5% and 24.9% for sheep, respectively (CSWRI, 2019). Arya *et al.* (1995) collected the *P. cineraria* foliage samples from different regions of the country and observed a wide range (18%-34%) of dry matter digestibilities. In another study, Dutta *et al.* (1999) reported improved digestibility of wheat straw on supplementing *P. Cineraria* leaves, such that they met 16 g DM/Kg$W^{0.75}$ of goats. The major factor limiting the higher level of inclusion of *P. cineraria* is presence of tannins at relatively higher levels (Bhatta *et al*., 2005). Raghavendra *et al.* (2007) reported that the amount of condensed tannins, hydrolysable tannins, and protein precipitation capacity of prosopsis foliage were 9.7%, 0.34%, and 11.5%, respectively. Presence of tannins at higher quantities interfere with microbial protein synthesis and digestibility coefficients of nutrients, especially crude protein. Inclusion of dried *P. cineraria* leaves at higher levels (20% by weight in the concentrate) in the ration fed to weaned lambs lowered the digestibility of organic constituents (CSWRI, 2019). Vaithianathan *et al.* (2007) reported decreased growth performance and microbial protein synthesis of lambs and kids fed diet containing *P. cineraria* leaf meal at either 50:50 or 75:25 ratios to concentrate feed. The same study revealed negative effects of Prosopsis leaf meal on wool production, and the performance was of higher proportion in goats compared to sheep. This observation could be attributed to relative resistance of goats to tannins compared to sheep. The adverse effects of *P. Cineraria* can be reduced by sun drying the leaves and pods.

P. Cineraria can be included in the rations of large and small ruminants, at large extent, on reducing the tannin levels by applying feed technology tools. Very little research has been carried out on *P. cineraria* efficient utilization and much investigation is needed on feeding management to exploit the beneficial effects of *P. cineraria* as low-cost feed, antibacterial, antifungal, antioxidant, and other medicinal properties.

Conclusion

Forage tree legumes act as a promising source of good quality protein feeds for ruminants and non-ruminants as these are the most commonly used and cheaply available feed sources, especially during drought periods. Although many different and some potentially dangerous compounds have been isolated from many of the potentially useful forage legume trees, little is known about the specific effects of these compounds on ruminant metabolism. Application of knowledge regarding feed processing technology, RDNA, and plant breeding and by adopting some managemental practices, the effect of toxins present in legume tree fodders on animal health can be minimized. Feeding these legume fodders also helps in reducing the feeding cost and good quality fodder can be made available to various livestock during extreme weather conditions. However, further investigation is needed for using fodder tree legumes, at higher levels, by eliminating the deleterious effects at cheaper cost.

Conflict of Interests

There is no conflict of interest.

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