CHAPTER I

INTRODUCTION
Plants or plant-parts of vegetation, which are meant for grazing or harvested as feed for livestock, are referred to as forages. Forage-based resources include: improved pastures, cultivated fodders, protein-rich foods from under-utilised plants and leguminous browse species, etc. These are important components of diet of livestock and provide desirable nutrients (proteins, carbohydrates, lipids, minerals, vitamins, etc.) for their proper nutrition, health and productivity. Forage plants and their seeds also contain many secondary metabolites, such as alkaloids, sterols, triterpenoids, saponins, flavonoids, estrogens, phenolic acids, oxalates, nitrates, trypsin inhibitor, etc.

Secondary metabolites in plants has always given a start to the discipline of Chemistry in every country of the globe. These compounds are important in medicine, industry and agriculture. Chemistry of plant kingdom is increasing in scope. Rare structures are being elucidated. There is better understanding of plant taxonomy. Quest for new compounds of pharmacological interest is continuing. Certain drugs are still natural products. The knowledge gained is being applied in industry. Some secondary metabolites are antinutritional in character and seriously effect the health and productivity of livestock and thus are being continuously explored.

Protein is a dietary essential. It is made up of amino acids. Some 19-20 amino acids enter into the make-up
of animal tissue. For normal growth of rats, pigs and chicks, threonine, valine, leucine, isoleucine, methionine, phenylalanine, tryptophan, lysine, arginine and histidine are essential to be provided in the diet. Other amino acids, viz., glycine, alanine, serine, cystine, aspartic and glutamic acids, tyrosine, proline and hydroxyproline are synthesised from essential amino acids in the body and termed as non-essential. Thus, for food to be used with maximum efficiency, the animal must receive indispensable amino acids in correct quantities.

Cereal grains and leguminous seeds are the most favoured components of diet of mono-gastric animals. The crude protein content in cereals generally varies from 8 to 12 percent and in legumes between 20 to 25 percent. Most of the proteins in these foods is in the form of simple proteins and stored as reserve material. These are mainly composed of albumin, globulin, prolamin and glutelin. Albumin and globulin have a relatively balanced amino acid composition. Prolamin is unsuitable as a source of protein. Glutelin has more desirable amino acid composition than prolamin. Earlier attempts to assess protein quality of seeds were based on fractionation of proteins into above major groups of simple proteins (Osborne, 1924). The premise of the study was that variation in amino acid composition of different seed proteins was reflected in the shifts of four major fractions. Thus, it is the most acceptable mode of assessing the protein quality of cereal and non-cereal grains.
However, the protein is generally preferred to be assessed in terms of its indispensable amino acid make-up. The two non-essential amino acids, cystine and tyrosine, are also routinely determined, as methionine can be partly replaced by cystine and similarly tyrosine can partly replace phenylalanine. Thus, the above essential and non-essential sulphur-containing amino acids and those possessing aromatic structure are frequently considered together for assessing the animal's requirements.

Chemically, the quality of protein may be estimated from its amino acid constitution in comparison to FAO/WHO (1973) recommended reference amino acid pattern or that of whole egg protein (Eggum, 1970). Such simple procedures for assessment of nutritional quality of protein include: chemical score, essential amino acid index, ratio of total essential amino acids (g) per g feed nitrogen, etc. The estimates of chemical score correlate well with the biological values for rats and human beings (Mitchell and Block, 1946, Eggum, 1970, Bender, 1973, etc.). Duggal and Eggum (1977) developed relationships for computation of biological values from the estimates of chemical scores of various foods. Essential amino acid index is based on ratios of amounts of essential amino acids in a protein, relative to their amounts in standard whole egg protein (Oser, 1951). For ruminant feeding, protein is determined as crude protein from feed nitrogen (N x 6.25) and protein quality is assessed on the basis of digestible crude protein content.
The main component of dry matter of plant and many seeds is carbohydrate. Plants store energy largely in form of soluble carbohydrates, such as, starch, sugars, etc. The cell-wall of plants and their seeds also consists of carbohydrate material. It mainly comprises of cellulose, hemicellulose and lignin. Cellulose and hemicellulose pertain to partially-available nutritive matter in feeds, which are digested by enzymes produced by microorganisms within the digestive system of the animals. Lignin possesses no nutritive value.

Lipids act as concentrated form of energy in the diets of humans and animals and fats contain 2.25 times as much energy as do carbohydrates for the same weight. Fixed oils from seeds contain a mixture of saturated and unsaturated fatty acids, including the essential (linoleic, linolenic and arachidonic) acids. The composition of seed oils is generally characteristic of the botanical family to which the plant belongs and thus varies greatly. The essential fatty acids are required to be provided in the diet for normal functioning of all animals. While fatty acid composition of seed fats is essential to be known for incorporation into diets of monogastic animals and pre-ruminant calves, ruminant animals absorb a variety of fats and oils with high degree of efficiency (Outon et al., 1974). Thus, the fat is generally estimated in terms of ether extract for organising feeding of ruminants.
Plants contain a wide variety of mineral elements, which are regularly ingested by animals. Some of them possess metabolic roles in the body and are termed as essential. Depending upon their concentration in the animal body, the essential minerals have been classified into major elements and trace elements. The concentration of calcium, phosphorus, potassium and sodium (15, 10, 2 and 1.6 g/kg respectively), among major elements, and iron, zinc and copper (20-80, 10-50 and 1-5 mg/kg), among trace elements, is relatively higher.

Alkaloids are physiologically active basic compounds of plant origin and have been known for a long time as toxic principles. They occur in many leguminous and graminaceous forages. Plants containing higher levels of alkaloids are unpalatable and often bitter. Phenylethylamine alkaloid concentration influenced the palatability of *Pennisetum americanum* (L.) K. Schum, when grazed by cattle (Rouquette et al., 1980). Reed canary grass (genus: Phalaria) contains indole alkaloids. Simons and Marten (1971) screened 411 diverse genotypes of reed canary grass for palatability in grazing sheep. Total indole alkaloid concentration was also implicated in lowered average daily gains in lambs and steers grazing reed canary grass (Marten, et al., 1976), while diarrhoea in grazing lambs was caused due to cultivars of reed canary grass containing tryptamine-carboline alkaloids.
(Marten et al., 1980). *Crotalaria* species contain pyrrolizidine alkaloids (Jones and Hegarty, 1981).

The sterols are neutral and comparatively stable substances. These are widely distributed in plant and animal kingdoms and occur partly in free condition and partly esterified with higher fatty acids or as glycosides. The basic skeleton consists of 17 carbon atoms arranged in the form of a perhydrocyclopentanophenanthrene.

Triterpenoids are classified on the basis of six isoprene units present in their molecules. They possess tetracyclic (lanosterol) or pentacyclic structures. The pentacyclic group of compounds are further subdivided into β-amyrin, α-amyrin and lupeol series based on the parent saturated hydrocarbons, ursane, oleanane and lupane respectively. β-amyrin type of compounds are found to occur widely in nature as alcohols or hydroxy-carboxylic acids. Some of the common naturally-occurring compounds are: taraxerol, lupeol, betulin, amyrins, ursolic acid, oleanolic acid, etc.

Saponins are biologically-active water-soluble plant glycosides. They yield sapogenins and sugars (glucose, galactose, rhamnose, xylose, etc.) on acid hydrolysis. The sapogenin has either a complex triterpenoid or steroidal structure. The biological activity of saponins appears to reside in intact glycoside than
the aglycone (sapogenin). They are bitter in taste. They stabilize foam in water. They are very powerful oil-in-water emulsifiers. They act as powerful haemolytics, when injected into blood stream, dissolving red blood corpuscles even at extreme dilutions. Saponins kill fish probably by disabling breathing mechanism of gills. This facilitated catching fish using crushed plants (containing high saponin levels) and stirring them into a pool. After a short time, fish rose to surface and were taken easily. Saponins are not absorbed from the intestines. Hence, fish killed by saponins could be eaten safely. Saponins occur in a wide variety of plants belonging to families: Leguminoseae, Liliacea, Dioscoreaceae, Scrophulariaceae. These are also found in food-stuffs, like, soybean, groundnut, peas, oat, tomato, asparagus, cucumber, yam, sugar-beet, blackberry, tea, etc. (Nakanishi et al., 1974; Cheeke et al., 1977; Birk and Peri, 1980; Price et al., 1987).

Flavonoids are an important group of compounds with 2 phenylbenzopyrone nucleus. These occur as free or as glycosides in plants. The sugar-free substances are termed as anthoxanthidins. Quercetin (a derivative of 3-hydroxy flavone) occurs in certain varieties of apple, oat bark and numerous other plant sources.

The isoflavonoids are biogenetically related to flavonoids. They are isomeric with flavones and differ
only in position in attachment of aryl (B) ring to central pyran nucleus. Most of the isoflavones possess estrogenic activity (Harborne, 1971). The main isoflavones occurring in *Trifolium pratense* and *T. subterraneum* are: genistein, biochanin A, diadzein, formononetin and pratensein. These substances have estrogenic activity and their presence in pastures causes problems of infertility in animals. Leguminous pastures with high concentration of formononetin showed enhanced estrogenic activity (Lindsay et al., 1970). Recently, a novel phytoestrogen has been reported from *Gopubia delphinifolia* G. Don (Saxena and Bhadoria, 1990) which also possessed estrogenic activity. The coumestran class of isoflavonoids is another large group of compounds occurring in *Medicago sativa* and *Trifolium repens*. These include: coumestrol, trifoliol, repensol, lucernol, medicagol and sativol. Kickoff et al. (1969), Todd (1970) and Wong et al. (1971) reported that above compounds also showed estrogenic activity in animals.

A number of aromatic acids are found in plants. These are not so universally distributed as are the aliphatic acids. These may occur as free acids or as esters and glycosides in association with essential oils. Commonly occurring aromatic acids are: cinnamic, p-coumaric, protocatechuic, ellagic, ferulic, sinapic, gallic and caffeic acids (Miller, 1964).
Oxalic acid in plant originates from the oxidation of a large variety of compounds (sugars, amino acids, alcohols and other carboxylic acids). It belongs to the category of strongly dissociated organic acids. The pH of cell sap in its presence may decrease to 3.1. Thus, certain plants, whose leaves or fruits accumulate relatively large concentrations of oxalic acid, can only survive when the acid is precipitated as calcium oxalate. Plants rich in oxalates are: spinach, napier, sugar beet leaves, paddy straw, Oxalis and Rumex species, etc. Cattle fed paddy straw or other grasses containing 2 percent or more of oxalates develop a negative calcium balance. Acute toxicity on account of oxalate ingestion may result due to hypocalcemia. It may be accompanied by an increase in plasma phosphorus, magnesium and sodium which may cause convulsions and tetany. Oxalate poisoning is further characterised by rapid and laboured respiration, depression, weakness, coma and death. Supplemental calcium reduces the toxicity due to oxalates.

Probably, a minimum amount of nitrogen is needed as nitrate to satisfy the requirements of plant growth. It may be equivalent to 0.1 percent nitrate-N in the plant tissue. However, under conditions of high nitrogen fertilisation, plants may accumulate nitrates to a very high level. Nitrates are toxic to ruminants. Nitrate is readily converted into nitrite in the rumen. Nitrite
enters blood and oxidises ferrous iron of haemoglobin to ferric state, producing brown pigment, methaemoglobin, which is incapable of transporting oxygen to body tissues. Thus, the effects of nitrate poisoning largely result from oxygen starvation or, in effect, suffocation. Toxic symptoms include: trembling, staggering, rapid respiration and death. There is also a risk of sub-clinical nitrate toxicity. It can result in poor growth, loss of milk, reproductive difficulties and symptoms of vitamin A deficiency. Prasad (1988) reported that forages, which accumulated 0.2 g nitrate-N per 100 g dry matter, were toxic to animals.

Trypsin inhibitor is widespread throughout the plant kingdom and especially among legumes. The most frequent source is the seed of the plant, although in field beans (*Vicia faba* L.) a high level can occur in leaves, as well. Synge (1971) suggested that comparative richness of trypsain inhibitor in legumes could be connected with symbiotic process of nitrogen fixation. Trypsin inhibitor inhibits the proteolytic activity of enzymes in the digestive tract. Thus, various treatments (heat, germination, fermentation, enzyme action, methionine supplementation, etc.) have been employed from improvement in nutritional value of legume proteins through reduction or inactivation of trypsain inhibitor.
The proximate analysis of plants is one of the most preferred methods for determination of concentration of crude protein and crude fat (Cullison, 1979). The plant cell-wall (neutral detergent fibre) is estimated by the recent methods of Van Soest and associates (1966 a, 1966 b, 1967, 1970). It mainly comprises of cellulose, hemicellulose and lignin. The nutritive availability of cell-wall carbohydrate is influenced by the proportion of lignin present. The lignin (as acid detergent lignin) is determined by the procedure proposed by Goering and Van Soest (1970). The estimation of lignin requires prior determination of acid detergent fibre. Thus, it allows computation of cellulose and hemicellulose contents in forages. The residual forage dry matter after subtraction of neutral detergent fibre is termed as neutral detergent solubles. These mostly consist of cellular contents (starch, sugars, proteins, lipids, soluble ash, etc.) and are highly digestible. Soluble carbohydrate in forages can be likewise computed by subtracting the sum of percentage of crude protein, crude fat and soluble ash from percent neutral detergent solubles (Harris, 1970). The organic matter has to be removed from the plant samples by dry ashing or wet digestion before the essential minerals are estimated following basic principles of inorganic analysis and using modern colorimetric and flame photometric methods.
A good amount of sophistication has been recently introduced in techniques of isolation, identification and structural elucidation of natural products. The chromatographic techniques, like column (Kari et al., 1977; Higuchi and Donelly, 1978), paper (Lederer and Lederer, 1957; Edward, 1963) and thin layer (Voirin and Jay, 1977; Kery et al., 1977) are in frequent use for separating pure compounds from complex mixtures. Resolution of proteins into constituent amino acids is being accordingly undertaken by ion-exchange chromatography.

Gas chromatography (Berl, 1956) is one of the most powerful separation techniques for the analysis of enormously complicated mixtures of hydrocarbons, alcohols, esters, etc. (Dilts, 1974). It is being extensively employed for the analysis of fats for individual fatty acids through their methyl esters.

The gas-liquid chromatography involves physical separation (by adsorption) of volatilised esters on an inert solid (silica gel or granules of ground fire brick coated with non-volatile lubricating grease or silicone oil) packed in a glass or metal column. A constantly flowing stream of inert gas (argon, helium or nitrogen) then keeps the volatilised esters moving which differentially emerge at the end of column depending upon their relative affinities for the inert solid (stationary phase).
A recent advancement of GLC is the introduction of high pressure liquid chromatography, wherein the separation is effected by the application of high pressure. Many workers have reviewed the application of HPLC for the separation of plant phenolics (Adams and Nakanishi, 1979; Vas Samere et al., 1979) including flavonoids. HPLC is particularly suited to the analysis of those compounds, which cannot be readily handled by GLC (Pryde and Gilbert, 1979). With the help of HPLC, thermally labile compounds can be analysed at ambient temperatures, highly polar compounds can be chromatographed without prior derivatisation and polymeric samples can also be analysed.

Investigations into many branches of chemistry rely to a considerable extent on the analysis of absorption spectra in the ultra-violet region (Lang, 1961). In practice, it is mostly limited to conjugated systems. Chromophoric groups are also detected. The selectivity of ultra-violet absorption is further useful in recognising characteristic groups in the molecules of widely varying complexities. It is widely used in the study of natural products.

Infra-red radiations are referable to visible and microwave region of the electro-magnetic spectrum (Dyer, 1978). The infra-red region extends from 2.5 to 15 μ (4000 to 667 cm⁻¹), while the region from 0.5 to 2.5 μ
(12,500 to 4000 cm\(^{-1}\)) is near infra-red and the region from 15 to 200 µ (667 to 50 cm\(^{-1}\)) is far infra-red. The functional groups present in a molecule have characteristic absorption bands and these bands are quite informative in the structure elucidation of compounds. Infra-red spectrum may also often distinguish between cis and trans isomers.

Mass spectroscopy is a well-established and an essential analytical tool in the structure determination of unknown natural products (Cooks and Johnson, 1971). It is possible to determine molecular weight, molecular formulas, nature of various functional groups and the relative position of double bonds. Rapid developments in the technique of ionisation have brought to light a variety of ways in which ions can be generated from an organic compound (Schulmeister, 1981). Of all the methods so far used, the conventional electron impact ionisation is by far the most common. However, certain compounds do not give peaks corresponding to molecular ions in their electron mass spectra and thus molecular weight information is not obtainable. The advent of chemical ionisation mass spectroscopy has partly solved this problem (Manson, 1977). Similarly, emergence of field ionisation and field desorption mass spectroscopy has facilitated the analysis of complex mixtures (Wood, 1982) without prior
separation. Thermally labile and non-volatile samples, such as glycosides, can also be studied without derivatisation.

Nuclear magnetic resonance spectroscopy has been used to detect and identify double bonds, determine the number of rings present and nature of end groups, and ascertain the orientation (o, m or para position) of methyl groups in the molecule. In certain cases, definite structures have been assigned on the basis of NMR spectra. Thus, the application of nuclear magnetic resonance spectroscopy has been accepted as one of the most powerful physical methods for structure elucidation of unknown organic compounds.

The perennial species of genus *Brachiaria*, tribe Paniceae, family, Gramineae, are capable of providing an excellent vegetative cover in denuded grasslands. *B. decumbens* and *B. dictyoneura* are important species for introduction as improved pastures (Thomas and Groff, 1986). Both outyield other tropical grasses under normal growth conditions and promote animal production (Thomas and Groff, loc. cit., Arias et al., 1985). Abate et al. (1984) reported the proximate composition of *B. dictyoneura*. The oxalate content in *Brachiaria* species was studied by Mathams and Sutherland (1952), Sood and Chopra (1973) and Adyanabo (1974). Bowden and Williams (1971) estimated
sterols in seeds of *P. ruziziensis*. These contained (percent by weight of total sterols) 2.79 percent cholesterol, 11.82 percent compesterol, 15.54 percent stigmasterol, 55.65 percent $\beta$-sitosterol, 13.6 percent $\Delta^5$-avenasterol and 0.6 percent $\Delta^7$-avenasterol. The hulls of maturing seeds of *P. ruziziensis* contained phenolic compounds. These were identified as vanillic, $\beta$-coumaric and ferulic acids (Renard, 1976). *P. mutica* was investigated for the presence of alkaloids (Ismail et al., 1977) and phytotoxic substances (Chou and Young, 1975).

Hybrid napier is one of the most important perennial fodder crops for the cultivated areas. It is an interspecific hybrid between pearl or bulrush millet (*Pennisetum americanum* (L.) K. Schum or *P. typhoides* (Burm.) S and *H* and napier or elephant grass (*P. purpureum* Schum.). Both the parents are tall and tufted grasses. Hybrid napier combines the fine textured, leafy, fast-growing, drought-resistant, succulent and palatable qualities of *P. americanum* with the high-yielding potential of *P. purpureum*. The earlier well-known varieties of hybrid napier are: NB-21, Pusa Giant and Puna Gajraj. The proximate composition of hybrid napier and oxalate content has been widely studied (Muldoon and Pearson, 1979). Govindaswami and Manickam (1987) determined the total fibre and lignin by Van Soest methods in variety BN-2. Phenylethylamine alkaloid has been shown to be present in *P. americanum*.
(Rouquette et al., 1980). However, no untoward effect due to feeding of hybrid napier as sole roughage to animals has been reported in literature.

Genus *Atylosia*, a member of family Leguminosae (Papilionaceae), consists of herbs and shrubs with twining, trailing, spreading and erect habits. Most of the *Atylosia* species are hardy perennials occurring naturally along with native grasses and have been a major source of nutrients. They are rich in protein and resistant to drought and diseases. *Atylosia* species are distributed throughout the tropics and subtropics. Sixteen out of twenty-five *Atylosia* species are endemic to India (De, 1974). *A. scarabaeoides* Benth. is widely distributed in the country, China, Mauritius and Madagascar. It is a slender herbaceous perennial creep-r. *A. albicans* Benth. occurs in western and central peninsular India. It is a twining shrub. *A. platycarpa* Benth. is found in Bengal and central India and up to 2500 m on western Himalayas. It is a herbaceous creeper (Duthie, 1960; Arora and Chandel, 1972).

The seeds of *A. scarabaeoides* and *A. albicans* were observed to be rich in protein (Reddy et al., 1979; Ramanandana, 1980). Proximate composition of *A. siricea* and *A. lineata* has been reported by Reddy et al. (loc. cit.) and Singh et al. (1981). Sharma and Gupta (1985) identified hentriacontane, β-sitosterol glucoside, D (+)-
pinitol, vitexin and four fatty esters of hexacosanol in the leaves of *A. scarabaeoides*.

Genus *Rhynchosia*, Leguminosae (Papilionaceae), produces twining or erect herbs or shrubs. It occurs everywhere in the tropics. *R. minima* (L.) DC is an annual herb, available during rains. It either twines on supports or spreads on grounds. It is widely distributed in the country, Ceylon, Burma and Sudan (Duthie, 1960; Arora and Chandel, 1972). *R. rothii* Benth. ex Aitch. is a twining perennial shrub. It is found in central and western Himalayas upto 2000 m (Arora and Chandel, 1972).

The leaves of *R. minima* were analysed for C-glycosyl flavones (Adinarayana et al., 1979), while its seeds contained hydroquinone diacetate and proanthocyanidins (Krishnamurthy et al., 1975; Kangaswamy et al., 1974).

The genus *Cassia*, Leguminoseae (Caesalpiniaceae), consists of 340 species and occurs as shrubs or trees throughout the tropics. *C. pumila* Linn. is a low very diffuse shrub with slender finely downy branches. It is distributed upto 2000 m in the Himalayas, western and eastern ghats and peninsular humid belt of the country (Duthie, 1960; Arora and Chandel, 1972).
The genus *Cassia* is the main source of anthraquinone derivatives (Raghunan than et al., 1974; Kudav and Kulkarni, 1974, etc.) A new flavonol 8-C glycoside was found to occur in *C. sophera* leaves (Tiwari and Bajpai, 1981) and another flavonoid, Javanin, has been reported from *C. javanica*, (Chakrabarty et al., 1984). *C. auriculata, C. laevigata, C. absus, C. siamea, C. podocarpa*, etc. were also chemically investigated for the presence of sterols and sugars, besides flavonoids and anthraquinones (Dai, 1977; Kostova and Rangaswami, 1977; Tiwari and Richard, 1979; and Lohar et al., 1981). Sharma and Gupta (1983) reported the presence of hexacosanol, \( \beta \)-sitosterol, physcion, emodin and rutin in *C. pumila* leaves.

*Desmanthus virgatus* (L.) Willd. is a perennial, palatable, 2-3 m tall, leguminous browse shrub. It is widespread in tropical zones of Asia and Africa, Australia, Iran, West Indies, etc. It is restricted to roadsides and unused blocks of land in Hawaii (Skerman, 1977). It has a remarkable tolerance to severe sodic soils.

The crude protein content of *D. virgatus* cut at 61, 91 and 122 days' interval was 10.6, 12.3 and 15.5 percent, and the average protein content in its leaves and stems was 22.4 and 7.1 percent respectively (Skerman, loc. cit.). A group of flavonoids (rutin, quercitrin,
myricitrin, kaempferol-3-\text{o}-diglucoside) were isolated from the leaves of *Desmanthus illinoensis* (Nicollier and Thompson, 1983).

*Dichrostachys cinerea* (L.) Wight and Arn. is another leguminous browse species. It is a small tree, usually 3-5 m high, with pods forming a valuable source of protein. It is distributed in tropical zones of Africa and Asia, Australia, Iran, Sudan, etc. (Skerman, 1977). Within the country, it is found in northern India, Madhya Pradesh, Rajasthan, Andhra Pradesh and Karnataka.

Van Rensburg (1968) found that the leaves and shoots of *D. cinerea* contained 15 percent crude protein, 21.16 percent crude fibre, 1.53 percent calcium and 0.18 percent phosphorus. The leaves of *D. cinerea* were eaten by camels and pods relished by cattle in Sudan (Tothill, 1954), while McKay (1963) reported that cattle and goats browsed the pods in Botswana. Van der Walt and Steyn (1939) reported that ground entire pods of *Dichrostachys nyassana* Taub. (25 g), after having been moistened with water for 24 hr, gave a fairly strong test for the presence of hydrocyanic acid. De Limelett (1958) observed that when *D. glomerata* bark was crushed and macerated for 30 min in water, the solution was useful for furuncle and blennorhoea treatment. It was also useful for preservation purposes in food industry. Krishnamoorthy and
Seshadri (1962) detected the presence of cyanidin in *D. cinerea* plant. Gmelin (1962) isolated dichrosta-chinic acid from the seeds of *D. glomerata*. Joshi and Sharma (1974, 1977) analysed bark, heartwood, leaves and roots of *D. cinerea*. The bark contained friedelin, friedelan-3 β-ol, α-amyrin and sitosterol. Octacosanol and sitosterol were isolated from heartwood. Leaves showed the presence of hentriacontanol, β-amyrin and sitosterol. The roots yielded n-octacosanol, β-amyrin, friedelan-3, one, friedelan-3 β-ol and β-sitosterol.

There is a vast gap between demand and supply of conventional forages and concentrates in the country. This calls for thorough study of newer and untapped sources of food for proper nutrition of livestock. Introduction of improved pastures in denuded grasslands and, in cultivated areas, establishment of newly-developed, high-yielding and multi-purpose hybrids of fodder crops constitute the most pertinent approaches for augmentation of existing roughage resources in the country. In respect of concentrates, legume seeds from under-utilised plants and browse species can act as a valuable protein supplement in the rations of animals.

*Brachiaria decumbens* and *B. dictyoneura* are important species for introduction as improved pastures in
tropical grasslands. The review of literature shows that these grasses have not been chemically examined for detailed nutrient composition, particularly in respect of Van Soest fibre fractions and essential minerals. Regrowths of monsoon months were studied for various nutritive attributes and toxic principles (oxalates and nitrate) in the present investigation. A review of literature further shows that *P. decumbens* and *P. dictyoneura* are phytochemically unexplored. The work on chemistry of above *Eragriaria* species was, therefore, also included in the study.

The three new multi-cut varieties of hybrid napier (Nos. 2, 3 and 6), developed by crossing short-day photosensitive *Pennisetum americanum* lines with local *P. purpureum* grass at the IGRI, offer good scope for establishment under a variety of agro-climatic conditions in the country. These hybrids alongside the most popular variety NB-21 have not been systematically studied for nutrient composition and toxic principles (oxalates and nitrate) during the productive phase of the crop in a year. Investigations on their nutritional quality as well as toxic principles and their seasonal variation were therefore undertaken in the present study.

The under-utilised leguminous plants selected for the study pertained to three *Atylosia* (*A. scarabaeoides*, *A. albicans* and *A. platycarpa*), two *Rhynchosia* (*R. minima* and *R. rothii*) and one *Cassia* (*C. pumila*) species. The seeds
of above plants form an important source of protein. They also contain some oil. No information on their seed protein quality and fatty acid composition of their fixed fatty oil is available in literature. Exhaustive studies on both aspects in the above six untapped sources of legumes were therefore carried out in the present investigation.

Desmanthus virgatus and Dichrostachys cinerea are two important leguminous browse species. They have got good production potential and are recommended for introduction in agro-forestry. No systematic attempt has been made to properly utilise their surplus seeds as a component of animal food. Information on their nutritional quality is also lacking. Detailed chemical composition and fatty acid composition of fixed oil of the above seeds was therefore investigated in the present study.

The present chemical investigations on quality and anti-quality factors in six forages and eight seed materials were, thus, expected to augment the existing quality feed resources in the country and thereby enhance availability of milk, meat, wool, eggs, etc. through balanced feeding of live-stock.

Investigations on nutrient composition, oxalates, nitrate and chemical constituents in monsoon regrowths of Brachiaria decumbens and B. dictyoneura are presented in Chapter II.
The forages were analysed for organic nutrients (percent crude protein, ether extract, cell-wall and its fractions and soluble carbohydrate), ash and its fractions (percent ash, acid soluble ash and acid insoluble ash), major minerals (percent calcium, phosphorus, potassium and sodium), trace elements (iron, zinc and copper, in ppm), oxalates (percent total, soluble and insoluble oxalates) and nitrate-N, in ppm. The chemical composition of the grasses showed that these were fairly nutritious in respect of organic nutrients and minerals. The soluble oxalate content (2.3 percent in both the grasses) was slightly higher than the level (2.0 percent) likely to be well tolerated by animals. Nitrate-N was present in traces (3.3 to 4.0 ppm).

Detailed investigations on the isolation and identification of naturally-occurring chemical constituents in *B. decumbens* and *B. dictyoneura* pasture grasses revealed the presence of known compounds of widely varying nature. The hexane fraction of leaves of *B. decumbens* contained a long chain aliphatic alcohol (hexacosanol) and a plant sterol (β-sitosterol). A sterol glucoside (β-sitosterol - β-D-glucoside) and phenolic acid ester (ethyl caffeate) were present in benzene fraction, while a flavone glycoside (quercetin-7-O-α-L-rhamnoside) was isolated from ethyl acetate fraction. The hexane, benzene and ethyl acetate fractions of leaves of *B. dictyoneura* were found to contain
a long chain hydrocarbon (hentriacontane) and related alcohol (hentriacontanol); another long chain alcohol (myricyl alcohol), sterol ester (β-sitosterol palmitate), and a flavone glycoside (rutin). These compounds were identified on the basis of spectral analysis, derivative formation and degradation studies. They were present as minor plant constituents and were not expected to pose any health problem when the pasture was grazed by animals. However, the presence of similar pattern of compounds in the two species of *Pachieria* may be of chemotaxonomic interest.

Chapter III deals with studies on nutritive attributes and oxalates and nitrate in three new IGRI varieties of hybrid napier (Nos. 2, 3 and 6) and their seasonal variation along with the most popular variety NB-21. Five regrowths pertaining to different seasons were studied. The forages were chemically analysed for the various nutritional parameters as detailed in Chapter II. The values for digestible crude protein, dry matter digestibility, dry matter intake and digestible dry matter intake were also computed. The results showed that protein-rich supplements may be required while feeding the fodder to high-yielding stock. The calcium: phosphorus ratio in the herbage (2.0:1 to 7.4:1) was wide, which needed to be corrected (to lie between 1:1 to 2:1) with the help of feeds rich in phosphorus or phos-
variety No. 2 was the most nutritious, followed by No. 3. The nutritional quality of forage was the maximum in the regrowth of March-April. The accumulation of various nutrients was next in order in the regrowth of July. There was a marked tendency for higher accumulation of antinutritional factors (total and soluble oxalates and nitrate-N) in nutritionally superior varieties as well as during favourable periods of regrowth. No ill-effect due to higher ingestion of oxalate was anticipated, as the forage contained sufficiently high amounts of calcium.

In Chapter IV, results on seed protein quality of six under-utilised leguminous plants (*Atylosia scarabaeoides*, *A. albicans*, *A. platycarpa*; *Rhynchosia minima*, *R. rothii* and *Cassia pumila*) along with fatty acid composition of their seed oil have been presented. The work involved determination of crude protein content, distribution of protein fractions, amino acid composition, chemical score, biological value of protein, essential amino acid index, ratio of total essential amino acids (g); seed nitrogen (g) and concentration of trypsin inhibitor. The seed oil was analysed for saturated and unsaturated fatty acid composition. The seed protein quality, in general, appeared better in *Atylosia* than *Rhynchosia* and *Cassia* species. An almost inverse trend was noted in fat quality
of seeds. The seed oil from *Cassia pumila* was nutritionally observed to be the most superior (concentration of 18:2 acid 57.7 percent). It could also be classed among "linoleic-rich drying oils" and thus assumed industrial importance.

The decoated seed powders of two leguminous browse species (*Desmanthus virgatus* and *Dichrostachys cinerea*) were studied for their chemical composition and fatty acid composition of their seed oil. The results are given in Chapter 7. Both the seeds could act as protein-rich supplements (crude protein 33.2 and 37.2 percent). The seed oil contained appreciably high amounts of palmitic acid (77.0 and 87.4 percent), thus making them the richest known natural source of C16 acid. The nutritional quality of seed oils of *D. virgatus* and *D. cinerea* could also be improved by inclusion of oleic acid-rich sources of fat or after suitably blending them with fat rich in polyunsaturated fatty acids (PUFAs), like, cotton seed, soybean or safflower seed oils.