The Potential of Mulberry Foliage as Feed Supplement in India

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A major constraint to animal production in developing countries is the scarcity and fluctuating quantity and quality of the year-round feed supply. These countries experience serious shortages in animal feeds of the conventional type. The grains are required almost exclusively for human consumption. By the year 2020, world population is expected to reach 8 billion and most of the population growth will occur in developing countries. With increasing demand for livestock products as a result of rapid growth in the world economies and shrinking land area, future hopes of feeding the millions and safeguarding their food security will depend on the better utilisation of unconventional feed resources which do not compete with human food. In addition, over-exploitation of soil resources has resulted in wide scale land degradation. This calls for not only better utilisation of already known unconventional feed resources but also for identification and introduction of new and lesser known plants capable of growing in marginal soils. The propagation of such plants can play a vital role in control of soil erosion, bring economic benefits to farmers, create jobs and bridge the wide gap between supply and demand for animal feeds. This would also lead to diversification in traditional agriculture and conservation of biodiversity through the sustainable utilisation of natural resources.

The rearing of livestock is an integral part of the economy of most of the developing countries. The economy of the Indian farmer is based to a large extent on animal production. The production is quite low as the animal is undernourished for a significant part of the year. The low productivity is exacerbated by long calving intervals and a late age of puberty. Crop residues and low quality forages are the major feed resources. The primary constraint to ruminant production on such feeds is the low efficiency of feed utilisation. Livestock development over the past three decades has been mainly directed towards satisfying the rapidly increasing demand for milk and meat in the urban centres. The resource-poor small farmers produce a major part of milk and meat. Appropriate technologies to improve performance of locally available animal and feed resources within the rural system are lacking. Animal productivity can be increased by the introduction of low cost technologies which improve current systems of husbandry. Acceptable and successful feeding systems are those that are simple, practical, consistently reproducible and within the limits of the farmer's capacity and available resources.

Fodder, the mainstay for livestock rearing is cultivated only on 4% of the total cultivable land in India and this figure has remained more or less static for the last three decades. Due to increase in human population the demand for food grains and other cash crops is increasing, resulting in lesser area for fodder cultivation. The denuded grasslands, pastures, forest openings and the forests are the major source of herbage for the livestock. The draft report of the Policy Advisory Group on Integrated Grazing Policy, Ministry of Environment and Forests, Govt. of India (1993) has indicated the current deficit to be 584 and 745 million tons of dry and green fodder respectively. The present level of availability of animal feeds indicates a deficiency of about 19%

DM, 55% DCP and 28% TDN for feeding the existing livestock population. The increasing human population, limited land holdings and the growing requirements of food grains for human population have direct impact on the livestock production.

Recent nutritional research has demonstrated the possibility of a large increase in animal production that can be achieved by alterations to the feed base (Leng, 1997). Production can be increased by up to five fold by providing the critical catalytic nutrients that are deficient in the diets and by balancing availability of nutrients closer to requirements. In the rangelands, particularly in the semi-arid areas, tree forages, seeds and pods represent by far the greatest potential source of protein meals.

In more recent times, trees and shrubs have been introduced into cropping and grazing systems to provide green fodder high in protein to supplement the available low protein forage. These are grown in banks or hedges, between crops (alley farming) or as a component of pastures and also shade trees. Multipurpose trees can make a significant contribution to agricultural systems by improving soil fertility and providing a variety of useful products, including valuable forage and wood. The feeding value of low quality roughages and grasses can be greatly improved by foliage from trees, which can be grown integrated directly to pastures and in fences. In some cases, pure stands of forage shrubs and trees can be the best option to intensify animal production replacing traditional low performing grass-based systems. The potential roles of tree foliage in ruminant nutrition are: a) high quality and high digestibility biomass resource, available in and around the farm, b) supplement to provide nutrients deficient in the diet resulting in enhancement of microbial growth and digestion of cellulosic biomass in the rumen, c) source of undegradable protein, d) source of vitamins and minerals to complement deficiencies in the basal fed resource, and e) reduction in the requirements for purchased concentrates and as a result decrease in cost of feeding.

Tree forages form an integral part of ruminant feeds in high altitudes of Himachal Pradesh, Jammu and Kashmir and Uttar Pradesh States of India. The use of tree forages as components of diets is a widespread practice in many tropical countries. Considerable diversity exists in the type of forage supplements of value, particularly to ruminants. Recognition of the potential of tree foliage to produce considerable amounts of high protein biomass has led to the development of animal farming systems that integrate the use of tree foliages with local bulky feed resources. In order to determine the suitability of trees/shrubs as components of ruminant fibrous diets, knowledge is required in many areas, including 1) the capacity and ability of the tree to regenerate foliage when grazed or harvested, 2) the feeding behaviour of animals when confronted with tree forages, 3) the voluntary intake of tree foliage under different environmental conditions, 4) the adaptation of trees to the local conditions and their potential to become weeds, 5) the growth pattern of trees/shrubs in relation to crops or pasture, 6) the required soil pH characteristics and nutrient status, and 7) the nutritive value of the foliage and its change with harvesting, grazing or cultivation.

The mulberry plant in tropical belt is grown as low bush while as high bush in temperate regions. In tropical conditions, individual leaf and branch harvest is done with a yield of 10 to 30 ton/ha/year, while it is shoot harvested in temperate regions with a leaf yield of 25 to 30 ton/ha/yr. The percentage of moisture, protein and carbohydrates are higher in temperate regions when compared to tropics. It is monoecious, occasionally dioecious shrub or moderate-sized tree with a fairly cylindrical straight bole, up to 3.0m high and 1.8m in girth. Leaves are very variable, ovate or broadly ovate, serrate or crenate-serrate, and often deeply lobed. The plant is frost-hardy but liable to wind-damage. It regenerates itself naturally from seeds which are dispersed by birds and to a limited extent by jackals and also human beings. It can be propagated artificially by seeds or cuttings. It grows rapidly in the early stages and reaches maturity at an early age; the growth rate falls off rapidly after approximately 10 years. It coppices vigorously and pollards well. When grown close in plantations, the tree develops a long clean bole.

At present in many other parts of the world, mulberry leaves are predominantly used for silk production, and therefore it will be pertinent to mention the status of silk production from mulberry in India which might encourage workers to develop strategies to integrate silk and livestock production at the village level resulting in higher income to farmers.

Silk production

Numerous types of mulberry are under cultivation in various silk-producing countries of the world; the types differ in their adaptability to various soils and climates, resistance to diseases, food value of the leaf crop for the silkworm and suitability for use as stock or scion in grafting. In Japan, the world's major silk-producing country, approximately 700 types of mulberry are known to exist, out of which 21 have been selected for extensive cultivation. Some of these types are adaptable to a wide range of climatic conditions.

The most important type of mulberry grown in India for rearing silk worms is *Morus alba* var. multicaulis Loud, which is a native of China or Philippines. It is fast-growing and adapted for cultivation as a field crop producing large, tender and thick leaves. *M alba* var. *atropurpurea* (Shahtut), also a native of China, is cultivated widely as a tree crop for its large, cylindrical, dark purple, succulent fruits. It is also fast-growing and yields large thick leaves, which are at the same time smooth, tender and succulent. The var. atropurpurea is recommended to be cultivated along the borders of bush plantations in Bengal.

Mulberry is grown on an extensive scale in various parts of India, particularly in Mysore, West Bengal and Jammu and Kashmir for its leaf, which constitutes the food for the silkworm, and its cultivation is an integral part of the sericultural industry. In some areas, it ran wild and spread in suitable localities. It is also grown as a road side and avenue tree. In the Himalayas, it ascends up to an elevation of about 1,200m. In the hills, it is mostly confined to stream beds or places where sufficient moisture is available. It does not grow on dry slopes or shallow soils where moisture is a limiting factor. The old leaves are shed in November - December and the trees are leafless during winter season. The new leaves appear in March-April depending upon the climate of the locality. The mulberry is a shade bearing tree and it can with advantage be grown as an understory with other light demanding species.

In Mysore and West Bengal, mulberry is grown as a field crop and leaves are harvested several times in the year to feed the multivoltine races of silkworm. In Jammu and Kashmir, it is grown as a tree and leaves are lopped only in one season for rearing the univoltine races of the worm. A system of growing dwarf grafted trees or 'high bushes' has been recently tried in West Bengal. It is also grown to a small extent in Punjab, Himachal Pradesh, Uttar Pradesh, Madhya Pradesh, Bihar, Orissa, Assam, Manipur and Andhra Pradesh States of India, where small quantities of silk are produced. The large acreage is in Mysore, which accounts for more than 75% of the total mulberry raw silk production in the country.

Young leaves which have attained full size are best suited for feeding silkworm larvae. The composition of leaves varies with variety, degree of maturity and the type of soil in which the plants are grown. The contents of protein and soluble sugars in leaves decrease with the maturity of leaves; fibre, fat and ash constituents increase. Young leaves are more acidic than older ones. Analysis of leaves collected from different silk producing localities in India gave the following ranges of values (% in DM): crude protein 16-39, soluble sugars 7.6-26 and ash 8-17.

India has the advantage of production of all the four known commercial silk varieties viz. mulberry, tusser, eri and muga in the world. Mulberry silk is domesticated and the rest are wild silks. India produces currently about 14,050 tonnes of silk of which mulberry alone accounts for more than 90% of total silk production. It is practised in over 60,000 villages in the country. Mulberry sericulture is well suited for marginal, small and landless farmers. It has an edge over other crops in the rural sector. It is estimated that one hectare of irrigated mulberry will generate employment for about 13 persons starting from mulberry cultivation to trading round the year, and that in the value addition 48.3 % goes to the farmer; 21.6 % to traders and the rest to weavers, reelers, twisters and dyers (Lakshmanan and Devi, 2000).

Year	**Area under mulberry (Million ha)**
1950-51	0.05673
1960-61	0.08295
1970-71	0.09424
1980-81	0.17000
1990-91	0.31310
1995-96	0.35000

In Himachal Pradesh, mulberry is grown as a shade tree on the wasteland, road sides, border of the fields and around farmer's house. Himachal Pradesh is predominantly a univoltine/bivoltine silk producing state. Mulberry leaves for silkworm rearing are collected from trees grown on the border of the fields, around the houses and on the wastelands under rainfed conditions. Family labour is employed in sericulture; women play a major role. Sericulture is adopted mainly by the small and marginal farmers and landless labourers as a subsidiary occupation.

The preferential food value of mulberry leaf for silkworm larvae is attributed to the presence in it of 3 stimulant factors, viz. an attractant, a biting factor and a swallowing factor. The substances which attract the larvae to the leaves have been identified as citral, linalyl acetate, linalol, terpinyl acetate and hexenol. β-Sitosterol (approximately 0.2% in leaves), along with some sterols and a water-soluble substance, is the main factor which stimulates the biting action.

Animal feeding

The leaf fodder of mulberry is reported to be of good quality and can be profitably utilised as a supplement to poor quality roughages. Leaf yield varies with the fertility of the soil, irrigation and frequency of plucking of the leaves. In West Bengal, one hectare of well manured and irrigated plantation can yield about 19 to 28 tons of leaves in five pluckings. On DM basis, the leaves contained 15.0 - 27.6 % crude protein (CP), 2.3 - 8.0 % ether extract (EE), 9.1 - 15.3 % crude fibre (CF), 48.0 - 49.7 % nitrogen free extract (NFE), 63.3 % total carbohydrates, 14.3 - 22.9 % ash, 2.42 - 4.71 % Ca, 0.23 - 0.97 % P, 0.196 % S, 1.66 - 3.25 % K, 350 - 840 ppm Fe (Jayal and Kehar, 1962; Singh *et al*., 1984; Singh *et al*., 1989; Makkar *et al*., 1989). The cell wall constituents were: neutral detergent fibre (NDF) 33 - 46 %, acid detergent fibre (ADF) 28 - 35 %, hemicellulose 5 - 10 %, cellulose 19 - 25 %, and lignin approximately 11 % (Lohan *et al*., 1979; Makkar *et al*., 1989). The content of total phenols was very low (1.8 % as tannic acid equivalent), and tannins by the protein precipitation capacity method were not detectable (Makkar *et al*., 1989; Makkar and Becker, 1998).

A prolamin has been separated from alcoholic (alkaline) extracts of mulberry leaves and it forms the principal protein of the leaves. The nitrogen (N) distribution in a preparation containing 12.6% N was as follows: HCl-insoluble N 0.50, humin N 0.45, amide N 0.96, diamino acid N (arginine N 0.89, histidine N 0.49, lysine N 0.35, cystine N 0.01) 1.74, and monoamino acid N 7.89%. Protein preparations from young mulberry leaves form an excellent supplement to protein-deficient diets.

Non-protein nitrogen accounts for approximately 22% of the total N in young leaves and approximately 14% in mature leaves. The amino acids identified in the free form are: phenylalanine, leucine, valine, tyrosine, proline, alanine, glutamic acid, glycine, serine, arginine, aspartic acid, cystine, threonine, pipecolic acid and 5-hydroxy pipecolic acid.

The mulberry leaves are thus rich in CP, EE, Ca and ascorbic acid (200-300mg/100g; 90% of which is present in the reduced form) and low in CF. They also contain carotene, vitamin B1, folic acid, folinic acid and vitamin D. The presence of glutathione in leaves has been reported. Copper, zinc, boron and manganese occur in traces. Phytate phosphorus accounts for 18 % of total phosphorus. Sulphur is required together with nitrogen for microbial protein synthesis in the rumen. Concentrations of sulphur greater than 1.5 g/kg dry matter or nitrogen : sulphur ratios less than 15:1 are considered adequate. Both these requirements are met in mulberry leaves. Similarly the levels of potassium and iron in mulberry leaves are also higher than their recommended levels (Fe 30-50 ppm, K 0.5-1.0 %) in diets (McDowell, 1997). High Ca content in mulberry leaves (2.4 -4.7 %) than the required level in diet (0.19-0.82 %; McDowell, 1997) could be useful for high yielding ruminants during early stages of lactation. Calcium is closely associated with phosphorus metabolism. High ratio of Ca:P in mulberry leaves could create some problem with calcium, phosphorus and vitamin D metabolism at high level of supplementation of leaves in diets. It has been suggested that high Ca:P is associated with infertility in cattle. It should be noted that the mulberry leaves usually would be used only a part of livestock diets.

The feeding experiments with sheep showed that the leaves are highly palatable. The digestibility coefficients for CP, EE, CF, NFE and total carbohydrates were found to be 71, 4, 54, 84 and 76 % respectively (Jayal & Kehar, 1962). The digestible nutrients per 100 kg of leaves on DM basis were 10.7 kg CP, 0.27 kg EE, 8.3 kg CF, 40.2 kg NFE and 59.6 kg total nutrients.

The leaves are also useful as cattle fodder; they are nutritious and palatable, and are stated to improve milk yield when fed to dairy animals. The feeding value of mulberry leaves is rated high by the livestock owners. Feeding experiments have shown that up to 6kg of leaves per day can be fed to milch cows without adversely affecting the health of animals or the yield and butter content of milk.

The mulberry leaf stalks remnants, left after feeding silkworms, can also be used for feeding cattle without any adverse effect on their health and performance. The chemical composition of leaf stalks (% in DM basis) was: 11.5 CP, 7.0 true protein, 2.7 EE, 34.0 CF, 42.5 NFE, 76.5 total carbohydrates, 9.3 total ash, 1.56 Ca, 0.20 P (Subba Rao *et al.*, 1971). Digestibility coefficients of organic matter (OM), CP, EE, CF, NFE and total carbohydrate were 58, 69, 73, 49, 60 and 56 % respectively. The balances of N, Ca and P were positive and the adult bullocks gained body weights during the experimental period.

Mulberry leaves can also be used in poultry ration. Incorporation of shade dried mulberry leaves in layer's mash to the extent of 6% showed an increase in egg production with desirable yolk colour without any adverse effect on body weight and egg quality (Narayana & Setty, 1977). Mulberry leaves, owing to their high carotene content, can form a valuable source of vitamin A for the health of poultry birds and increased egg production.

The effect of supplementing mulberry leaves *ad libitum* to concentrate diets of Angora rabbits on wool production has been studied by Singh *et al*. (1984). The average intake of mulberry leaves was 10.4 g/d/kg W $^{0.75}$ while the total DM intake was 29.5 g/d/kg W $^{0.75}$. The digestibility coefficients for DM, CP, CF and NFE were 69, 66, 72 and 78% respectively. The nutritive value of mulberry leaves (% in DM) calculated by difference was digestible crude protein 9.8 and total digestible nutrients 64. The results indicated that mulberry leaves can be advantageously incorporated in the diets of Angora rabbits for wool production. Mulberry leaves may be supplemented up to a level of 40 % of the DM with impunity.

Recently, studies have been conducted at the Regional Station of Indian Veterinary Research Institute, Palampur on characterisation of mulberry leaves for digestion kinetics parameters and comparison of these values with other tree foliages (Devarajan, 1999). Degradation kinetic parameters as studied by the *in vitro* gas production technique (Menke *et al*., 1979) showed that the potential gas production in young leaves was 60.6 ml/200 mg while the rate of degradation was 0.0703. The corresponding values for the mature leaves were 35.4 ml and 0.0624 respectively, indicating the fall in fermentability with maturity. The potential gas production for the young leaves was highest amongst the forages studied and the rate of gas production lower compared to only *Moringa oleifera* (Table 1), suggesting high nutritive value of the young leaves. The fermentability of the mature leaves was also high and comparable to *Leucaena* leaves. The high rate of gas production for mulberry indicates high intake potential of this forage.

The rate, potential extent and effective degradability (at passage rate of 0.05/h) of dry matter using the *in sacco* method of Orskov and McDonald (1979) were 0.0672, 85% and 52% respectively. These values for CP were 0.0467, 95% and 57% and for NDF 0.0368, 82% and 43% respectively. The effective dry matter degradability of various *Leucaena* species has been reported to be 46-51% (Tolera *et al*., 1998) and the value obtained in India was 51 % (Table 2). For mulberry leaves, the kinetic parameters for CP were also comparable to those for other good quality tree fodders (Table 3)

Table 1. Potential and rate of gas production from some tree forages

Forage	Potential gas production (ml/200 mg)	Rate of gas production
Acacia catechu	24.4	0.0456
Albizzia stipulata	17.4	0.0586
Artocarpus lakoocha	51.1	0.0379
Bauhinia variegata	23.1	0.0308
Dendrocalamus hamiltonii	33.8	0.0256
Ficus roxburghii	42.6	0.0462
Leucaena leucocephala	37.2	0.0578
Morus alba (young)	60.6	0.0703
Morus alba (mature)	35.4	0.0624
Moringa oleifera[1]	49.5	0.0852

1, from Makkar and Becker (1996)

Table 2. Rate and potential extent of dry matter degradation (PD) and effective degradability (ED) of dry matter (passage rate of 0.05/h)

Forage	Rate	PD	ED
Acacia catechu	0.0390	55	33
Albizzia stipulata	0.0348	32	24
Artocarpus lakoocha	0.0953	85	57
Bauhinia variegata	0.0489	42	27
Dendrocalamus hamiltonii	0.0347	56	26
Ficus roxburghii	0.0647	93	56
Leucaena leucocephala	0.0693	75	51
Morus alba (mature)	0.0467	85	52

Table 3. Rate and potential extent of crude protein degradation (PD) and effective degradability (ED) of crude protein (passage rate 0.05/h)

Forage	**Rate**	**PD**	**ED**
Acacia catechu	0.0295	42	14
Albizzia stipulata	1.0907	22	21
Artocarpus lakoocha	0.0693	93	64
Bauhinia variegata	1.2233	53	51
Dendrocalamus hamiltonii	0.0283	75	35
Ficus roxburghii	0.0540	95	60
Leucaena leucocephala	0.0426	78	43
Morus alba (mature)	0.0672	95	57

In sacco 48-h degradability (%) values for DM, CP, NDF and NDF-linked N were 76, 87, 70 and 79 respectively. It is clear from these values that nitrogen linked to NDF is degraded in the rumen to a considerable extent but depending on the rate of passage could well serve as source of undegradable nitrogen. The leaves of *Artocarpus* and *Ficus* are regarded as the most valuable fodder by farmers in the hilly areas of Nepal and India. The degradability values for mulberry are similar to those for *Leucaena leucocephala, Artocarpus lakoocha* and *Ficus roxburghii* (Table 4).

The contents of NDIN and ADIN in mulberry leaves were 56.5 and 20.4% of the total nitrogen respectively. The solubility of nitrogen (as % of total nitrogen) in borate phosphate buffer was 17.3% and in phosphate buffer was 15.7%. These values are of order similar to those for *Leucaena*, *Artocarpus*, *Dendrocalamus* and *Ficus* (Table 5). It was interesting that all the soluble N in mulberry was in the NPN form.

Table 4. *In sacco* degradability (48 h) of dry matter (DM), crude protein (CP), neutral detergent fibre (NDF) and neutral detergent fibre bound nitrogen (NDF-N)

Forage	DM	CP	NDF	NDF-N
Acacia catechu	47	34.	28	11
Albizzia stipulata	30	25	2	0
Artocarpus lakoocha	85	92	75	90
Bauhinia variegata	42	64	20	27
Dendrocalamus hamiltonii	45	57	39	51
Ficus roxburghii	88	86	84	87
Leucaena leucocephala	72	71	58	56
Morus alba (mature)	76	87	70	79

Table 5. Solubility of nitrogen (N) for some tree leaves

Forage	(% of total N)	
	Borate phosphate buffer (pH 8.1)	Phosphate buffer (pH 6.8)
Acacia catechu	21.5	13.0
Albizzia stipulata	21.6	12.2
Artocarpus lakoocha	16.9	14.6
Bauhinia variegata	42.0	23.5
Dendrocalamus hamiltonii	14.5	12.3
Ficus roxburghii	14.4	14.8
Leucaena leucocephala	19.1	13.3
Morus alba (mature)	17.3	15.7

From the *in sacco* data; the values for rumen degradable nitrogen (RDN), rumen undegradable nitrogen (UDN) and rumen undegradable but available post-ruminally (DUN) calculated are shown in Table 6, and the values for digestible organic matter, metabolisable energy and intake potential calculated from the gas production data in Table 7.

Table 6. Rumen degradable nitrogen (RDN), rumen undegradable nitrogen (UDN) and rumen undegradable but available post-ruminally (DUN) of some tree forage calculated at passage rate of 0.05/h (values are g/kg DM)

Forage	RDN	UDN	DUN
Acacia catechu	4.8	28.7	16.0
Albizzia stipulata	7.3	28.4	11.6
Artocarpus lakoocha	19.7	11.4	4.6
Bauhinia variegata	16.9	16.1	9.45
Dendrocalamus hamiltonii	11.1	20.6	11.2
Ficus roxburghii	13.2	8.9	2.6
Leucaena leucocephala	14.6	19.1	5.8
Morus alba (mature)	16.3	12.2	5.8

Table 7. Digestible organic matter (DOM), metabolisable energy (ME) and intake potential calculated from the gas data production data

Forage	DOM (%)	ME (MJ/kg)	Intake potential (g/kg $W^{0.75}$)
Acacia catechu	45	10.5	58.2
Albizzia stipulata	44	6.8	65.8
Artocarpus lakoocha	63	9.1	58.8
Bauhinia variegata	42	7.6	47.7
Dendrocalamus hamiltonii	40	6.7	46.5
Ficus roxburghii	54.9	9.2	62.0
Leucaena leucocephala	59.1	13.1	69.6
Morus alba (mature)	64	11.3	61-72
Moringa oleifera[1]	74	9.5	--

1, from Makkar and Becker (1996)

It is evident from the data presented in the above tables that the nutritive value of mulberry is as high as some of the well known good quality fodders. In addition, tannins at high levels are present in leaves of most trees (see Makkar and Becker, 1998), whereas mulberry leaves are free of tannins. Mulberry leaves have the potential to be used as a supplementary feed for increasing livestock productivity in crop residue-based livestock systems.

It has been a popular misconception that low productivity of ruminants in developing countries is mainly the result of the low energy density (low digestibility) of the available forages. There is now abundant evidence that low productivity stems from an inefficient utilisation of the feed resources because of deficiencies of nutrients (mainly nitrogen, sulphur and minerals) in these diet. Maximum fermentation rates are attained when all factors required by the ruminal micro-organisms are available - a source of energy (sugar, cellulose, hemicellulose), nitrogen, sulphur and minerals, and also when the nitrogen release and the energy availability are synchronised. Ruminants fed low quality forages require supplementation with the critically deficient nutrients to optimise productivity. Mulberry leaves being rich in nitrogen, sulphur and minerals their supplementation could increase the efficiency of utilisation of crop residues by increasing the efficiency of microbial protein synthesis in the rumen leading to higher microbial protein supply to the intestine. Recent concept of diet formulation is based on the manipulation of the diets in order to achieve high efficiency of microbial efficiency and high production of microbial protein in the rumen by creating an efficient rumen ecosystem. An associated advantage of achieving high efficiency of microbial protein synthesis in the rumen is the lower emission of environmental polluting gases - methane and carbon dioxide from feeds. Combination of trees and grassland would obviously be a desirable development and synergistic for cattle production. Strategic supplementation is justified because of regular feed shortages that occur and the fact that ruminants subsist for most of their life on fibrous crop residues on small farms. For high producing animals the feeding strategy should also be aimed at supplementation with bypass protein of dietary origin in addition to creating an efficient ecosystem. The genetic potential of superior livestock will only be realised if feeding systems are developed to ensure that the supply of essential dietary nutrients matches requirements for higher levels of production.

The use of high protein mulberry tree fodder should be encouraged to provide supplementation of crop residues and natural pastures thereby increasing productivity and the overall use of available on-farm biomass. Mulberry tree forage is well accepted by ruminants, pigs, poultry and rabbits. There is a need for systematic research on the optimisation of the use of this tree forage and develop strategies for its optimum supplementation under different feeding situations. The promotion of mulberry should be viewed in context of a holistic farming systems approach with the aim to increase income of the farmer, generate employment and conserve environment. An attractive option appears to achieve an integration of silk production and livestock rearing. Acceptance of these strategies could reduce the need for land clearing and pasture establishment in the fragile areas of the world which are prone to erosion following clearing.

According to one estimate, a total of approximately1.2 billion hectares of land in the world is degraded, barren or marginal and its proportion is increasing every year. Mulberry is an ideal tree species for economic management of unutilised wasteland (under rainfed conditions) for the following reasons:

- It is tap rooted with minimum superficial roots
- It has good coppicing power and is tolerant to lopping and pruning. Pruning and training of mulberry enhances the size and quality of leaves.
- It has easy generation capacity through seeds and vegetative means.

- It is a multipurpose tree which yields fodder, fibre, fruit, wood etc. The leaves are highly palatable and nutritious for livestock, and these are used extensively for silk production.
- Many varieties of mulberry are available which can grow in varied agro-climatic conditions in both temperate and tropical areas.

Mulberry has a potential to play a valuable role in world agriculture. It is an extremely versatile plant which can fulfil a number of roles in smallholder agricultural production. Its value is multifaceted and the potential for increasing and diversifying its use is enormous. However, its value and benefits as high quality supplements to low quality roughages in ruminant feeding systems have neither been widely known nor fully exploited. There is a wide genetic diversity in this species. It is a species of wide-ranging soil and climatic adaptation - a large number of provenances are available which grow under different soil and climatic conditions. Systematic studies are warranted to: evaluate these provenances in order to know the superior genotypes, collect and maintain germplasm, and conduct agronomy and management studies (e.g. environmental adaptation; establishment and propagation; defoliation management of tree; planting density, cutting intervals and cutting heights in intensive forage production systems; seed production) in different agroforestry systems (e.g. agrosilvoculture, agrosilvo-horticulture, silvopasture, energy plantation, boundary plantation, alley cropping and perennial cropping). This will improve biomass production with high nutrients for livestock feeding and extend ecological range of the plant. The future role and value of mulberry will depend on the outcome of these programmes.

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