

Current Uses of Cactus Pear (*Opuntia ficus-indica*) as Forage in Northern Ethiopia and Farmers' Indigenous Knowledge on its Utilisation

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Abstract

This study was initiated to assess the overall contribution of cactus pear under the prevailing harsh conditions in northern Ethiopia with particular emphasis on its current production and utilisation as an animal feed. The survey was conducted in two zones of Tigray region that are known for their cactus production and utilisation. Two hundred thirty (230) randomly selected smallholder farmers were interviewed using semi-structured questionnaires. This was supplemented by information obtained from key-informants. The adaptation of cactus to the region was evaluated using observation of its stands (vegetative measurement and density) and by comparing the ecological and/or bio-climatic requirements of the plant vis-à-vis agro-climatic data of the region. To assess the current status and prospect of cactus pear in the region policy related documents and plans and actions of institutions were reviewed. The multipurpose cactus pear fits well into the farming system and contributes significantly to combating food and feed insecurity. The main current uses of cactus are food (fruit), feed (cladode), live fence, source of income, soil and water conservation and land rehabilitation, with varying order of importance between the study areas. Cactus pear is used as forage by all farmers over 9-12 months a year. The main problems associated with feeding cactus include bloat, diarrhoea, coiling of fibre in the rumen, sore mouth and dropping and wear of teeth. Agro-climatic and edaphic conditions in the region and similar arid and semiarid areas of the country are most ideally suited to cactus pear production. The potential of cactus as source of food, feed and income seems to expand and even extend to the food, drink, dye, cosmetic and medicinal industries.

Key words: Cactus pear, *Opuntia*, forage use, indigenous knowledge, survey, arid

Introduction

The increasing requirement for human food in Ethiopia is progressively forcing farmers of the highland and mid-altitude areas to cultivate more land at the expense of grazing pasture and browses. Consequently, the contribution of natural pasture and range resources, which used to account for about 78% of the feed supply in

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the country (Alemayehu, 2006), have been seriously reduced and livestock depend increasingly upon crop by-products. For instance, in some areas such as Tigray, there are times when 65% of the total feed supply may come from crop residues and stubble grazing, which unless supplemented, are seldom adequate for livestock maintenance let alone for production. However, only one percent of the farmers in Tigray use forage crop during the dry season (WBISPPPO, 2003). These common feed resources are dry, contain a high proportion of cell wall and are deficient, among others, in water-soluble carbohydrates.

There has been a growing interest in the utilisation of locally available non-conventional feed resources to improve forage supply in smallholder livestock farms. Experts recommended planting trees and shrubs to provide feed resources so that herds and flocks are able to survive critical periods of shortfall and prolonged droughts (Le Houérou, 1996). Thus, screening of drought tolerant species should be taken as one of the research priorities in Ethiopia (Alemayehu, 2006) and elsewhere. In screening plants for animal nutrition in drought prone regions, drought tolerance and palatability for animals are the two most important criteria. Dry matter yield, digestibility, nitrogen/crude protein contents, adaptability of forage to marginal lands, ease of propagation and persistency are also of importance.

After its introduction in the mid-19th century to Ethiopia, cactus pear (*Opuntia ficus-indica*) has become one of the most common plants in northern Ethiopia particularly in Tigray, where it is integrated into the farming systems. Apart from Tigray, cactus is present predominantly also in other arid and semi-arid areas of Ethiopia. But, as can be seen in Debre Zeit and Bale, it also thrives in higher-rainfall highland areas. It grows in a variety of soil types, but does best in well-drained sandy loam soils (Le Houérou, 1996; De Kock, 2001). So far, there have been no formal studies on the distribution and use of cactus in Ethiopia. However, a general survey in Tigray showed that cactus is used for a range of purposes, mainly as food and forage (SAERT, 1994). The first step in evaluating a new or unconventional feed resource is to gather information from farmers in the area where the plant is grown (Preston, 1995). Though surveys on the traditional production and utilisation of cactus as animal feed were done in Tigray, they were conducted during the dry season only and with limited area coverage; in one district of the eastern zone (Hailu, 1998) and in one peasant association per zone (Mengistu and Udén, 2003); sample size (100 and 56 farmers, respectively) and different methodology (peasant associations selected randomly). In this study, data were collected during the rainy season, with more area coverage and sample size (230 interviewees selected from 32 villages, 3 districts and 2 zones), and for two consecutive years so that inter-year and inter-survey area comparisons could easily be made. This study was initiated to generate baseline information about the overall contribution of cactus pear for forage under the

prevailing harsh conditions in northern Ethiopia, the problems associated with feeding cactus, traditional prevention and treatment practices, farmers' indigenous knowledge in its utilisation and to assess the current status and prospects of cactus pear.

Materials and methods

Study Area

Though cactus pear is found widely distributed in the arid and semi-arid areas of Ethiopia, it was realised at the outset that a country-wide survey would only produce superficial information. Attention was, therefore, directed to detailed surveying of contrasting, but representative areas (Raya Azebo and Irob and Ganta-Afeshum districts) in the southern and eastern zones, respectively, of Tigray, northern Ethiopia, which are known for their cactus pear production and utilisation. The survey areas generally represent different agro-ecologies and soil types. The altitude and annual average rainfall of the study areas in the two zones range from 1300-3250 m above sea level and 300-600 mm, respectively. Average minimum and maximum temperatures were 5 and 28 °C, respectively. The dominant soil types are sandy silt, red clay loam, fluvisol and litosol. The survey areas in the eastern zone have inherently low soil fertility, while rainfall is the most limiting factor for plant growth in Raya Azebo district. There is also variation in arable land availability; the average land holding in Raya Azebo district was four times greater than Irob district (BoANR, 2002, unpublished). Cattle are the dominant livestock type in Irob and Ganta-Afeshum districts, followed by sheep and goats in that order while in Raya Azebo district the proportion of sheep and goat is almost equal and camels account for 5% (BoANR, 2002, unpublished). The dominant crop types in Irob and Ganta-Afeshum are barely and wheat, while sorghum and maize are dominating in Raya Azebo. Consequently, there are variations in cropping pattern, relative land productivity and food and feed security status in the study areas.

Sample Stratification, Data Collection and Statistical Analysis

The survey was undertaken at three levels, namely *Tabia* (peasant association), *Kushet* (village), and household (HH) levels. Purposive sampling technique was used to select three *Woredas* (districts) from the southern and eastern zones of Tigray. Similarly, 14 peasant associations were selected from the three districts. A total of 32 villages and 230 HHs were randomly selected. Data were collected in single visit interviews using semi-structured questionnaires. The questionnaires covered issues related to farmers' current practices and indigenous knowledge on the production and utilisation of cactus. The questions focused on: whether or not farmers own cactus, type of cactus ownership, variety, production practices, current uses, practices of feeding cactus to animals (when, how, to which livestock type, in what frequency), farmers'

perception (opinions and views) on its quality, problems in processing and after feeding cactus and traditional prevention and treatment practices for its safe use. Data collected by using questionnaires were supplemented by information obtained from key-informants and substantiated by cross-questioning, making field checks at the time of survey and secondary data derived largely from the Bureau of Agriculture and Natural Resources (BoANR) at district levels. Cactus fruit market survey was done in four locations (Maychew, Mehoni, Mekelle and Adigrat) of the two zones. Data on fruit quality, amount transacted, prices and number of people involved were collected. Cactus pear's adaptability to the region was evaluated using observation of its stands (vegetative measurement and density) and by comparing the ecological and/or bioclimatic requirements of the plant (Inglese, 1995; Nobel, 2001) vis-à-vis agro-climatic data of the region (WBISPPPO, 2003). Policy related documents, plans and actions of institutions were reviewed in order to assess the current status and prospect of cactus. The collected raw data were systematically coded and analysed using descriptive statistics.

Results and discussion

Cactus Pear Production System

Cactus pear ownership in the study areas is either communal or private (Table 1). On average, about 63% of the respondents have cactus pear in their backyard or homestead. However, there were clear differences between study areas. All farmers in Irob district of eastern zone have both communal and private cactus pear to produce fruits and forage while those in Ganta-Afeshum district of the same zone have private type of ownership. In contrast, relatively more farmers in Raya Azebo district of the southern zone, where about 64% of cactus plant is found (SAERT, 1994), do not have cactus in their backyard. If farmers of Raya Azebo district have cactus in homesteads, it is mainly for live fence, which is also used for fruit production and livestock feed.

Table 1: Type of cactus pear ownership in the study districts (%)

Zone	District	Private	Communal	Both
Southern	Raya Azebo	18.4	34.2	47.4
Eastern	Ganta-Afeshum	100.0	0.0	0.0
Eastern	Irob	69.1	10.2	20.7
	Average	62.5	14.8	22.7

All farmers have both spiny and spineless cactus; the spiny variety is dominant even in Ganta-Afeshum district. It is also surprising to note that more farmers (55%) in Irob district prefer spiny to spineless cactus pear because, they believe, feeding spiny cactus after burning decreases the water content of cladodes and consequently bloat and diarrhoea. This may show the importance the farmers give to the above disorders.

Farmers in Irob district, where cactus pear is believed to be introduced first, have a longer familiarization with the plant than others. They named more than 60 local 'varieties'; while those in the other two districts named only 14 'varieties'. The criteria for traditional classification were mainly based on fruit characteristics that include taste, colour, size and shape, which are basic fruit quality parameters (Mondragón, 2002). Farmers also use internal quality parameters such as total seed and water content. Presence or absence of spines, amount of spine per fruit and cladode, height of the plant and size and shape of cladode are some of the additional criteria used. These criteria clearly show that the forage aspect is considered during variety selection though it may be secondary. Some farmers mentioned the presence of poisonous 'varieties'. The available farmer-identified 'varieties' deserve further characterisation and identification.

About 80% of the farmers in Irob plant cactus pear during the long dry season (September-June). The remaining (20%) plant before the rain starts or stops. Farmers are aware of poor establishment during the rainy season due to decaying of cactus plant by excess moisture. None of the farmers treat planting materials with pesticides. Farmers usually use selected 'varieties' for planting material. In agreement with scientific recommendations (Mondragón, 2002), farmers in Ganta-Afeshum district cut the material to be planted from young plants, usually below six years. In the same district farmers carefully cut cactus cladodes below the joints and wilt. While 95% of the farmers in Irob district plant cactus in a pit, most respondents in Raya Azebo do not do so. In agreement with SAERT's (1994) report, the land that was selected for planting is not suitable for conventional crops (cereals and pulses). Assuming land is equitably distributed; this may imply that farmers who plant cactus might have more land and therefore produce more food and feed than their counterparts. Manure application to cactus pear plant was common in Ganta-Afeshum district (72%), while in the other districts negligible number of farmers apply manure (e.g., 5% in Irob).

General Current Uses of Cactus Pear

Cactus is used for a range of functions with varying order of importance between zones and between districts within the eastern zone (Table 2). The primary current use is that cactus fruit is the main source of food, especially during the rainy season (June-September), when food scarcity is at its worst. In some areas consumption of cactus fruit for food extends up to December.

Cactus is an income source for resource poor people (mainly school children and women). During the peak cactus fruit selling month (early August) more than 3350 street vendors were involved in selling cactus fruit in four locations only and they were able to double their income. Any attempt to improve harvesting practices and thereby fruit quality could increase the income vendors are getting.

Table 2: General current uses of cactus pear as first-ranked function by interviewed farmers

Use	Study districts (number of respondents = 227)							
	Raya Azebo		Ganta-Afeshum		Irob		Overall	
	Rank	%	Rank	%	Rank	%	Rank	%
Food (fruit)	3rd	24.2	1st	37.5	1st	37.5	1st	31.7
Forage	1st	29.3	2nd	30.7	2nd	25.0	2nd	29.1
Income	4th	16.2	3rd	14.8	5th	7.5	4th	14.1
Fence	2nd	26.3	4th	10.2	3rd	17.5	3rd	18.5
Others	5th	4.0	5th	6.8	4th	12.5	5th	6.6

As a living fence around houses and crop lands, spiny cactus saves other thorny plants that are usually cut for fencing and reduces deforestation of the already sparse vegetation. It serves as fuel source as well. Cactus is also planted on hilly and degraded lands to reclaim land, as a biological control and to strengthen physical structures built against soil erosion. However, its impact on soil quantity and quality is not yet studied. Cactus pear flowers during the dry months (January to March) when most other plants are not flowering and serves as a vital source of bee forage.

Cactus Pear as Forage

According to 93% of the respondents, livestock population size per HH has declined mainly due to drought and the consequent feed and water shortages (81%). Feed shortage is severe, especially in the study zones of Tigray region (WBISPPO, 2003). Recurrent drought and consequently feed and water scarcity have increased the demand for cactus as forage. A parallel account has been reported by López *et al.* (2001) in Mexico. Especially since the 1960s, as elders recalled, cactus pear has become a fodder crop of prime importance. It is palatable, a vital source of water (cactus fed cattle stay two to three days without water) and easily available during dry seasons and drought periods, when other forages are not.

All farmers use cactus as forage during much of the feeding calendar (9-12 months a year) depending on drought occurrence or rain availability (Fig. 1). While cactus feeding extends to June, farmers in Irob district start using it earlier than those in Ganta-Afeshum, mainly related to availability of crop residues and aftermath. Around Atsbi, eastern zone, the importance of cactus is reported to be crucial during the peak rainy season (June to August) (Assefa, 2005). Animals may also graze on the communal or wild cactus through out the year, whether there is drought or not.

All livestock types (cattle, sheep, goats, camels and equines) are reported to consume cactus pear. Cutting the cladodes and superficial burning to eliminate spines and chopping are the dominant form of processing cactus pear (85%). Few use scraping or rubbing to eliminate spines. Farmers burn both sides of the cladodes by putting straw or firewood on the cactus. To save firewood some households prepare traditional oven and add small amount of fuel on it. Traditional sharp materials like knife and sickle are

used to cut and chop the cladodes; none of the respondents were using specially designed tools. In order of importance, cattle and sheep are fed with processed cactus, either because they are preferred or their inability to graze *in situ*; only 15% of the farmers prepare cactus for equine while camels and goats do not face problems to browse even the spiny cactus.

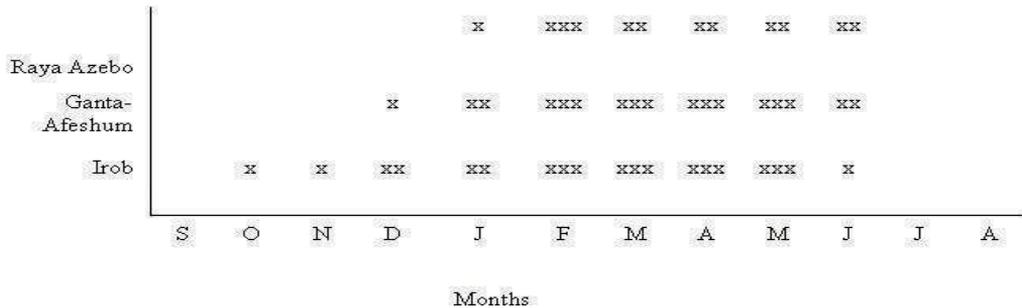


Fig. 1. Feeding calendar of cactus pear in the three districts during 'normal' years

About 86% of the respondents feed prepared cactus to their animals once daily, either in the morning or evening. Draught oxen and lactating cows, however, are fed more frequently. Some 45% of the respondents (Table 3) feed cactus alone; not because they do not know the consequences, but rather due to either feed shortage or farmers believe that the animals may consume what is available in the wild.

Table 3: Response of farmers to the different methods of feeding cactus pear to animals

Ways of feeding	Number of respondents	%
Alone	96	44.7
With crop residues	93	43.3
Either alone or with crop residues	26	12.0
Total	215	100

About 63% of the farmers feed their animals with young cladodes, if available, because it was preferable in terms of quality (palatability, and ability to walk long distance and body condition of cactus fed animals), while about 90% use young and moderate age cladodes. Moderately young cladodes are fed when there is scarcity of young cladodes and lack of labour. Farmers believe there are fewer side effects (bloating and diarrhoea) in feeding moderately young cladodes. In Ganta-Afeshum district, however, moderately young or old cladodes are used because there is no communal cactus and cactus holding is small that there is conflict of interest between fruit and forage uses.

According to 65% of the respondents, cactus supplementation increases milk production, but they believe that water content of the milk increases with level of feeding. About 35% reported that cactus supplementation does not bring visible change. In contrast, farmers characterised the meat of cactus fed animals as 'clean' and 'fatty/soft' and therefore

more preferred to lean meat. Farmers associated feeding young cladodes with improved body condition and shiny coat hair of animals, which are vital in price negotiations in selling live animals in Ethiopia.

Cactus pears' high productivity, adaptation and easy establishment were appreciated by farmers who favour the plant. Based on indigenous quality criteria, cactus has been preferred to, for example *Acacia etbaica*, which is also important in the study areas. Cactus is one of the preferred fodder species in Hawsi Dogu'u and Dogu'u villages of Tembien, central Tigray (Kindeya and Yemane, 1997). In Raya Azebo district, however, cactus was ranked at the bottom probably a protest against the fact that cultivable land is being infested with the plant and its invasion is on the increase, according to 82% of the respondents. This is clearly the result of mismanagement of the plant in the southern zone and should not overshadow its strategic importance. On average, 53% of the farmers believe that one of the mechanisms of controlling cactus invasion is using it as feed resource, which is the most economical and environmentally friendly way of controlling it from becoming weed.

Problems in Using Cactus Pear as Forage

Processing difficulties

Spiny cactus being the dominant variety, fuel shortage to burn the spines, labour, time, physical injury by spines and flames and discomfort related to heat and smoke are the major problems associated with processing cactus pear. Burning the spines is causing deforestation and environmental degradation. After cutting the cladodes and burning the spines farmers have to transport the bulky cladodes to their animals, which is a tiresome job. In addition, farmers in Raya Azebo district mentioned sunstroke while burning spines as a problem, which may be related to the prevailing high day-time environmental temperature.

Problems Associated with Feeding Cactus Pear

All farmers reported that the main problems associated with feeding of cactus are bloat and diarrhoea. Coiling of fibre in the rumen, sore mouth and dropping and wear of teeth are also identified as problems. Coiling of fibre might be due to feeding of unchopped old cladodes whose digestibility is very low (Le Houérou, 1996). Bloat and diarrhoea commonly occur in oxen and lactating cows that consume excess amount of cactus. In agreement with the finding of Mengistu and Udén (2003), bloat was reported to be more severe when animals are fed on cactus for the first time.

As indicated by 70% of the respondents, lack of proper feeding management and high water content of cactus are the major causes for bloat and diarrhoea (Table 4). In addition, farmers (100%) in Irob associated severity of bloat with feeding of cactus pear

and *Acacia etbaica* together, especially from April to September. Farmers also associated bloat with feeding cactus infested with insects locally known as “*Chanchu*” which belong to the family of ants. Though Mengistu and Udén (2003) reported that stock death due to bloat is common, only 20% of the farmers claimed that *ad libitum* feeding of cactus pear alone might result in death of animals.

Table 4: Main causes of bloat and diarrhoea which are associated with feeding of cactus to animals

Causes	Number of respondents	%
Improper feeding practice*	156	70.1
High water content	67	29.9
Total	223	100

*Overfeeding and feeding alone

Traditional Practices for Safe Use of Cactus as Forage

Traditionally, farmers developed their own prevention practices against problems that occur due to cactus feeding. Farmers (60%) are well aware that the best way of preventing bloat and diarrhoea is feeding cactus with dry feeds. When available, almost all farmers (97%) feed dry roughage before cactus. However, the optimum inclusion level that prevents bloat and diarrhoea is not known. Restricting cactus consumption by animals when fed alone is also practiced, which seems impractical as these are the times when nothing else may be available. Allowing the burnt cladodes to cool, mixing the cactus with salt, supplementing cactus with local beer residue and chopping the cladodes are also practiced.

Drenching the animals with diluted detergent is the most common treatment practice against bloat, followed by drenching with oil (Table 5). The use of detergents is seemingly related to proximity to towns. Drenching with mixture of flour of barely malt (fermented solution), dung, egg, pepper and soil with water is practiced by some farmers. Farmers smash a local plant called “*Amamgmel*”, mix with water and drench to animals suffering from bloat. Allowing the animal to run, pulling its tongue by hand and inserting a smooth stick in to the oesophagus of the victim are also practiced. At extreme cases farmers pierce the left abdomen between ribs. The scientific merit of some of the traditional treatment practices should be investigated.

Table 5: Traditional bloat and diarrhoea treatment methods practiced by farmers

Traditional treatment method	Number of respondents	%
Drenching with detergents	136	62.2
Drenching with oil	54	24.4
Drenching with local plant species	11	5.0
Others	18	8.4
Total	219	100

Current Status and Prospects of Cactus Pear

The observation of good cactus plantations in Tigray and comparison of the agro-climatic and edaphic requirements of the plant (Inglese, 1995; Nobel, 2001) with the agro-climatic data of the region (WBISPPO, 2003) showed that cactus could be grown in all areas of Tigray. Cladodes of the southern zone were significantly ($P<0.05$) wider, longer and heavier than those from the eastern zone (Table 6), which could be related to the agro-climatic and edaphic differences (WBISPPO, 2003). In southern Tigray, cactus has colonized open cultivated farmlands. Though cactus could be an important forage source for any area that suffers from feed and water shortages in dry seasons and drought periods, relatively little attention has been given to its potential in other areas than Tigray.

Table 6: Cladode size of spiny wild cactus pear collected from the southern (Raya Azebo district) and eastern (Irob district) zones of Tigray region

Zone	Width, cm	Length, cm	Wet weight, g
Southern	19.7a	36.7a	733.3a
Eastern	15.0b	29.3b	428.4a
Mean	17.3	33.0	580.9
±S.E.	2.03	3.47	94.26
P value	*	*	**

Different superscripts in a column show presence of statistical differences

* $P<0.05$; ** $P<0.01$

In Tigray the interest in cactus has remarkably increased and led to the identification of cactus pear as one of the food security crops. The BoANR is using cactus pear for its extensive rehabilitation of degraded lands (Gebreyohannes, 2004; personal communication). Mekelle University considered the potential of the plant and was involved in organising an international workshop (Mintesinot and Firew, 1997), which sparked interest in cactus. This has resulted into a FAO funded project (TCP/ETH/2901(A)) which mainly focused on screening the applicability of technologies developed elsewhere for the full exploitation of the plant in Tigray.

Conclusions and recommendations

Being a multipurpose plant, cactus fits well into the farming system. Farmers of the eastern zone have rich traditional experience in its production and utilisation compared to their counterparts in the southern zone of Tigray. Production and utilisation practices in Tigray are based on empirical knowledge and could be advanced through additional scientific information and modern technologies. Cactus is primarily used as source of food. Recurrent droughts and the consequent scarcity of feeds and water have increased the demand for cactus forage. Farmers use cactus pear as forage over 9-12 months a year and have rich indigenous knowledge on how to process and feed cactus and treat problems associated with its feeding. This should be

supported by scientific investigation. The main problems associated with feeding of cactus to animals are identified to be bloat and diarrhoea. Since all of cactus processing difficulties are related to the presence of spines, the spineless variety has to be promoted. Conditions in Tigray and similar arid and semiarid areas of the country are most ideally suited to cactus pear's production. The interest in cactus especially in arid and semi-arid areas has remarkably increased and the plant could be an important forage source for any area that suffers from feed and water shortages. It has tremendous potential in food, natural dye, medicinal and cosmetic industries (Barbera, 1995). Determining the optimal supplementation level of cactus, its role as a source of water and complementarity with locally available feeds are believed to be priority research areas. Though there are farmer identified 'varieties' no characterisation and selection have been done to improve cactus pear's potential as forage. Differences in drought resistance, palatability, crude protein content, plant habit, etc. among varieties need investigation.

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References

- Alemayehu Mengistu, 2006. Country pasture/forage resource profiles, Ethiopia. <http://www.fao.org/AG/agp/agpc/doc/Counprof/Ethiopia/Ethiopia.htm> (accessed November, 2006).
- Assefa Abegaz, 2005. Farm management in mixed crop-livestock systems in the northern highlands of Ethiopia. PhD Thesis, Wageningen University, The Netherlands.
- Barbera, G. 1995. History, economic and agro-ecological importance. In: Barbera, G. Inglese, P. and Pimienta-Barrios, E. (Eds.), *Agro-ecology, cultivation and uses of cactus pear*. FAO Plant Production and Protection Paper, 132. pp.1-11.
- De Kock, G.C. 2001. The use of *Opuntia* as a fodder source in arid areas of South Africa. In: Mondragón, C. and Gonzalez, S. (Eds.), *Cactus (Opuntia spp.) as forage*, FAO Plant Production and Protection Paper, 169, pp. 73-90.
- Hailu, H. 1998. Survey of cactus utilization in Ganta-Afeshum Woreda, eastern Tigray and evaluation of cactus as feed and water source for sheep. M.Sc. Thesis. Alemaya University, Ethiopia.
- Inglese, P. 1995. Orchard planting and management. In: Barbera, G., Inglese, P. and Pimienta-Barrios, E. (Eds.), *Agro-ecology, cultivation and uses of cactus pear*, FAO Plant Production and Protection Paper 132, Rome, pp. 78-91.

Kindeya Gebrehiwot and Yemane Asgedom, 1997. *Opuntia ficus-indica* and its role in reforestation. Proceedings of the international workshop on *Opuntia* in Ethiopia: The state of knowledge in *Opuntia* research. Mekelle, Ethiopia. pp. 154-175.

Le Houérou, H.N. 1996. The role of cacti (*Opuntia* spp.) in erosion control, land reclamation, rehabilitation and agricultural development in the Mediterranean Basin, *J. Arid Environ.* 33, 135-159.

López, G.J.J., Fuentes, R.J.M. and Rodríguez, R.A., 2001. Production and use of *Opuntia* as forage in northern Mexico. In: Mondragón, C. and Gonzalez, S. (Eds.), Cactus (*Opuntia* spp.) as forage. FAO Plant Production and Protection Paper, 169, pp. 29-36

Mengistu Weldehana and Uden, P., 2003. Survey on the traditional utilisation of Beles or prickly pear cactus (*Opuntia ficus-indica*) as animal feed in southern and eastern zones of Tigray. Proceedings of the 11th annual conference of the Ethiopian Society of Animal Production (ESAP), Addis Ababa, Ethiopia. pp.103-112.

Mintesint Behailu and Firew Tegegne (Eds.), 1997. Proceedings of the international workshop on *Opuntia* in Ethiopia: State of knowledge in *Opuntia* Research. Mekelle, Ethiopia.

Mondragón, C. 2002. Mission report on cactus pear (*Opuntia* spp.) production and utilisation TCP/ETH/2901(A). Mekelle, Ethiopia.

Nefzaoui, A. and Ben Salem, H., 2001. *Opuntia* spp.: a strategic fodder and efficient tool to combat desertification in the WANA region. In: Mondragón, C. and Gonzalez, S. (Eds.), Cactus (*Opuntia* spp.) as forage, FAO Plant Production and Protection Paper, 169, pp. 73-90.

Nobel, P.S. 2001. Eco-physiology of *Opuntia ficus-indica*. In: Mondragón, C., Gonzalez, S. (Eds.), Cactus (*Opuntia* spp.) as forage, FAO Plant Production and Protection Paper, 169, pp. 13-20.

Preston, T.R. 1995. Tropical animal feeding: A manual for research workers. FAO Animal Production and Health Paper 126, Rome, 305 pp.

SAERT (Sustainable Agriculture and Environmental Rehabilitation in Tigray), 1994. Prickly pear cactus production and processing, Vol VII, Mekelle, Ethiopia.

WBISPPPO (Woody Biomass Inventory and Strategy Planning Project Office), 2003. A strategic plan for the sustainable development, conservation and management of the woody biomass resources, Final draft. Addis Ababa, Ethiopia.

