The Integration of Fodder Shrubs and Cactus in the Feeding of Small Ruminants in the Arid Zones of North Africa

A. Nefzaoui
INRA Tunisia, Rue Hedi Karray, Ariana 2049 Tunisia

Abstract
In the arid and semi-arid zones of North Africa, animal feed resources are fluctuating and insufficient. Small ruminants are basically fed on rangelands. During the last three decades, the contribution of rangelands to the needs of livestock decreased from 80 to 30%. Therefore, to reduce the increasing deficit of feed resources and to preserve the rangelands, large scale plantations of spineless cactus (*Opuntia ficus indica*, var. *inermis*), *Acacia* (*Acacia cyanophylla*, Lindl.) and *Atriplex* (*Atriplex nummularia* and *A. halimus*) were established recently (400,000 hectares in Tunisia).

The benefits of these species include high biomass yield, evergreen character, drought resistance, tolerance to salinity and soil adaptability.

These plantations were first established mainly on communal lands but recently more and more were established on mixed crop/livestock farms and private land.

Opuntia and shrubs are planted in wide rows allowing cereal cropping (mainly barley) in between. Animals may therefore graze the increased herbaceous biomass between the rows during spring, and stubbles during the summer time. The seasonal supply of feed is then better adjusted to the animals' needs, and livestock feeding is based more on farm resources than on commercial feeds. Indeed livestock farmers, and especially small herd owners, face dramatic difficulties during the frequent drought seasons. They are often forced to sell a large number of their flock in

order to buy either rarely available expensive straw and hay or imported cereal-based feeds.

Nutritionally, the above mentioned species complement each other. *Opuntia*, rich in water and carbohydrates, gives sufficient energy, *Atriplex* provides protein and *Acacia* is a fibre source.

Nutritional characteristics of these species and their use in combination with other farm resources such as treated straw will be discussed.

Opuntia pads have low crude protein (20 to 50 g/kg DM) and crude fibre (80 to 150g/kg DM) contents. However, they have high contents of water (800 to 900 g/kg fresh weight) and ash (150 to 250 g/kg DM). Cactus helps to meet the animals' water requirement. In addition, cactus pads are rich in vitamin A (almost the only source under harsh conditions) and in readily available carbohydrates. However, they need to be supplemented with nitrogen. On the other hand, poor quality diets may be correctly supplemented with cactus. Our work showed that the intake of straw increased significantly with the amount of cactus in the diet. Moreover, cactus is a good supplement to ammonia- or urea-treated straw because it provides the carbohydrates needed for the efficient use of non-protein nitrogen. Other trials clearly demonstrated that energy and nitrogen requirements of sheep may be met using cactus-based diets supplemented with *Atriplex* sp. Indeed, it is possible to get good performances by feeding animals cactus and *Atriplex* ad libitum with limited amounts of hay and barley. Such diets are recommended during drought years in arid and semi-arid zones.

Diets based on limited amounts of straw (17%) and various amounts of *Atriplex nummularia* (24 to 59%) and spineless cactus (21 to 56%) can cover 165 to 180%, and 165 to 230% of the sheep's maintenance requirements, in energy and digestible crude protein terms, respectively. Such diets, using low inputs of cereal grains and forage crops, are recommended to cope with the feed deficiency prevailing in the North African arid and semi arid areas.

Acacia cyanophylla Lindl. is a leguminous fodder tree that is widespread in North Africa. *Acacia* leaves are high in crude protein (14% DM), lignin (ADL, 16% DM) and condensed tannins (4,5% DM catechin

equivalent). Their nitrogen is poorly digested by the animal because of the condensed tannins. Air drying or polyethylene glycol (PEG 4000) treatment help to overcome this problem. PEG may be added in drinking water or included in feed blocks in order to efficiently increase the performance of animals fed *Acacia* leaves.

Trials were carried out with sheep to investigate the effect of air-drying and polyethylene glycol (PEG) treatment of *Acacia* leaves on intake, digestibility and growth. A decrease in condensed tannin content was observed when Acacia leaves were air-dried or treated with PEG. Drying and PEG treatment significantly increased nitrogen utilization. Crude protein digestibility of *Acacia* averaged 18.6, 17.2 and 68.8% for fresh, air-dried and PEG-treated leaves, respectively. The beneficial effect of PEG treatment was also supported by growth trials.

KEY WORDS: *Opuntia*, prickly pear, nopal, *Acacia cyanophylla*, *Atriplex*, PEG, North Africa, feed, small ruminant

Introduction

The North African climate is characterized by an extreme irregularity both in space and time (succession of rainy and dry years, high thermal amplitude, long dry season, etc.). Drought is a frequent phenomenon that must be coped with it.

The key problem of the arid and semi-arid zones in North Africa may be summarized as follows (Oram, 1995):

i. The increasing degradation of rangelands in the steppe zones and the consequent decline in feed supply for ruminants.
ii. The continuing increase in the number of small ruminants, especially sheep, despite widespread indications of declining productivity of the natural grazing.
iii. Uncertainties about the rights to graze animals on the range, arising from changes in the traditional tribal regulation mechanisms consequent on privatization of the range and settling of migratory peoples.

iv. Demographic changes and increasing population pressure on natural resources, both directly through competition of people for land and water and indirectly through rising demand for meat and other animal products.
v. The limited availability of technology for improving sustainable range productivity. This is because of the lack of support for range research, inexperience of management of range flora, and a "reservation-type" rather than a participatory approach by government officials to establishing and utilizing forage shrub plantations.

Fodder Shrubs: An Attractive Alternative for Rangeland Improvement

Experience with fodder shrubs started in the early 60's and even earlier in some countries (Tunisia), with various degrees of failure and limited success. Their impact is difficult to assess, since monitoring and evaluation processes are lacking most of the time.

In Tunisia, for example, according to a recent survey, rangelands cover some 5,413,000 ha distributed in forest and forest pasture (970,000 ha), *Stipa tenacissima*-based steppe (743,000 ha), communal and state rangelands (2,500,000 ha), and private rangelands (1,200,000 ha).

National strategies for rangeland rehabilitation were initiated in most countries. The most important components of these strategies are plantations of shrubs. The main species used are spineless cactus (*Opuntia ficus indica* var. *inermis*), *Atriplex* sp. (mainly *A. nummularia* and *A. halimus*), *Acacia cyanophylla* and *Medicago arborea*. Species or varieties of shrubs were not selected for each particular environment and production system.

The cost of establishment is often high. For Tunisia, the approximate cost of establishment (including the maintenance and subsidies to farmers during the first 3 years) is about 750 US$/ha for cactus and 1000 US$/ha for other shrubs .

Current Management of Shrub Plantations

Since the beginning, shrub plantations were established on communal lands under the supervision of forestry departments. Most plantations are kept ungrazed by forestry people, who are more interested in soil conservation, or exposed to uncontrolled communal grazing which frequently leads to their degradation. Thus, several constraints appear rapidly and are due to poor management.

Numerous questions arise when considering the use of introduced shrubs:

i. How should introduced shrubs be used by the animals (cut-and-carry vs. grazing)?
ii. How frequently can they be grazed?
iii. What stocking rate can shrublands support?
iv. For how long can shrublands be grazed without permanent damage?
v. Should plants be completely defoliated or would they recover better if only partly defoliated? etc.

In the absence of a well-defined management strategy, continuous grazing is the prevailing management system. Lands are permanently exploited to their maximum potential with no compensatory input.

Unfortunately, little effort has been devoted to defining convenient strategies for the management of introduced shrubs. Once planted on communal, state or private rangelands, shrubs have to be maintained for at least three years before their use by animals. Subsidies, as feed (concentrate, hay, alfalfa pellets), are given to farmers to replace outputs of the improved rangelands during the maintenance period (first three years). After three years, introduced shrubs are supposed to be properly used as recommended. Under Tunisian climatic conditions, shrubs are used from two to five years following their establishment, depending on the zones (north or south regions) and on rainfall. In Tunisia, the use of shrubs is based on field experience of farmers and technicians. No adequate seasonal or annual calendars have yet been recommended to farmers.

Acacia cyanophylla trees are used by animals every two years. Plants are grazed one year and browsed the following year. Leftover branches and leaves are cut and distributed to the animals.

Cactus plantations are never grazed directly. The cut-and-carry technique is the common practice. Using such techniques, the loss of feed is virtually nil and the risk of over-utilisation is considerably reduced. The cut-and-carry technique is, however, costly in labour and the grazing layer of herbage remains unavailable to the stock.

Saltbushes (*Atriplex* spp.) are grazed during the summer season. Plants are rarely cut for regeneration.

Meanwhile, shrubs are used in different ways depending on the users' preferences. On private rangelands, shrubs are well managed and properly used. Their use is confined to the farmers' needs to fulfill seasonal animal feed demands according to technical advice. Nevertheless, these shrubs are subject to over-use during dry years and, consequently, plants hardly survive. On communal land and on rangelands under forestry department control, the use of established plants is dictated by the forestry technicians. Plants can be used shortly after their establishment (but not before three years). However, the use of rangelands (either rehabilitated with shrubs or not) by farmers' flocks is allowed only during dry years. To use improved and/or protected rangelands, farmers have to pay a fixed fee which varies between 0.3 and 0.4 US$ per animal. Meanwhile, most protected forest and communal rangelands are often not used by animals for many years. Such practice leads to early aging of shrub plants which become woody and less productive in terms of browsing. Their periodic cutting will favour the growth of new shoots and leaves and results in an increase in the production of fodder.

Better Adoption and Better Management of Shrubs on Private Lands

Within the WANA region, Tunisia may be considered as a leader in promoting the establishment of shrubs on private farms and their integration into the current feeding calendar.

From 1990 to 1995, the Rangeland and Livestock Office (OEP) initiated the establishment of some 50,000 ha of cactus and 7,400 ha of various shrubs (*Acacia, Atriplex, Medicago arborea*) on 20,000 private farms. Most of these plantations were located in central Tunisia (arid zones) where there is a permanent feed shortage (table 1).

Table 1: Area of shrubs established by the Pasture and Livestock Office on private farms during the last five years (1990-1995) Zones

	Spineless cactus (ha)	Other fodder shrubs (ha)*
North-east	1669	1623
North-west	2772	1449
East central	9674	1495
West central	33099	528
South	2712	2265
Total	49926	7360

*Main shrub species are: *Acacia cyanophylla* Lindl., *Atriplex nummularia* and *Medicago arborea*.

It can be noted from Table 2 that spineless cactus is the main species used for rangeland rehabilitation. The largest areas of cactus plantations are located in the west central region of Tunisia (governorates of Sidi Bouzid, Gafsa and Kasserine). Using cactus pads for feeding animals has been a common practice for a long time. Cactus, a low protein, bulk foodstuff, is regarded as an emergency feed and is cultivated as such in Tunisia as part of the drought evasion strategies for livestock. Moreover, cactus feeding considerably reduces the drinking water requirement as it contains 80 to 90% of water (Ben Salem *et al.*, 1996).

In contrast to the other fodder shrubs, cactus establishment is accepted without problems by the farmers since they are familiar with this species. At the farmer level, cactus may serve as a fodder resource and also for human consumption of the fruits. However, the benefit expected from the other fodder shrubs is limited and the absence of a strategy for their management is the main constraint to their acceptance by the farmer as a tool for rangeland rehabilitation. In addition, it should be stated that the number of shrubs used for rangeland rehabilitation in the national strategy is too small to allow for better selection of species adapted to the micro-climate of each region.

Integration of Shrubs in the Production System - Some Promising Results

Spineless Cactus : A Strategic Fodder for Arid Zones

The benefit of integrated use of cactus is discussed in the following examples and case studies.

EXAMPLE 1: Nutritive value of diets based on spineless cactus (*Opuntia ficus indica* var *inermis*) and *Atriplex* (*Atriplex nummularia*) (Nefzaoui and Ben Salem, 1996).

Barbarine wethers were randomly allotted to 3 equal groups and fed diets based on cactus (*Opuntia ficus indica* var. *inermis*) and *Atriplex* (*Atriplex nummularia*) (80% of the diet). Restricted amounts of wheat straw (180 g/d) and commercial mineral and vitamins supplement (30 g/d) were distributed.

Dry matter intakes (DMI) were similar for all the groups (930 to 983 g DM/d or 70 to 73 g DM per kg $LW^{0.75}$). The relative intakes of Atriplex and cactus in the diets were 59 and 21%, 41 and 38%, and 25 and 56%, respectively for diet 1, diet 2, and diet 3. Digestibility coefficients of organic matter (OMD) and crude protein (CPD) of the 3 diets were relatively high, averaging 68 to 74%, and 75%, respectively. In contrast, fibre digestibility was low, probably because of the soluble carbohydrate content of cactus which depressed rumen cellulolytic activity. Nitrogen retentions were 4.1, 3.9, and 4.1 g. nitrogen per day for diet 1, diet 2, and diet 3, respectively (table 2).

The diets provided about 170% of the sheep's energy and digestible CP (DCP) requirements. Diet 1 provided 1.65 and 2.3 times the energy and DCP requirements of the sheep, respectively. Thus, it has an excess of nitrogen and may be supplemented with an energy source like barley grain. Diet 2 is relatively well balanced in both energy and nitrogen, while diet 3 has an excess of energy and needs to be supplemented with a nitrogen source (non protein nitrogen, like urea).

Voluntary intake of cactus was high (6.8 kg/d or ~550 g DM/d). No digestive disturbance was observed on any of the diets. Organic matter (OMD) and crude protein (CPD) digestibilities of the 3 diets were high.

Nitrogen retention was positive for the 3 diets and may indicate the relative good quality of nitrogen supplied by *Atriplex.*

In conclusion, cactus is a good source of energy and *Atriplex* a good source of nitrogen. Energy and nitrogen requirements may be matched by using diets based on these two feeds. The level of cactus in the diet may reach 55% on a DM basis, without digestive disturbances. A small amount of fibrous feed (straw, hay) has to be fed to the animals before feeding cactus. More efficient use of the diets could be achieved if the mineral balance is improved.

Table 2: Nutritive value of diets

Diets	D1	D2	D3
Total intake g DM/d*	941(70)	930(72)	983(73)
Cactus intake	197	353	550
Atriplex intake	554	391	236
Straw intake	160	159	167
Diet OMD, %	67.7	69.3	74.4
Diet DCP, %	74.5	76.6	75.5
Retained N, g/d			

* the values ( ) correspond to intakes stated in g of DM per kg of $LW^{0.75}$

EXAMPLE 2: Nitrogen supplementation of cactus-based diets fed to Barbarine yearlings (Nefzaoui *et al.*, 1996).

The objective of this research was to investigate the effect of a nitrogen supplement (urea, soya bean meal, *Atriplex halimus* or *Atriplex nummularia*) on voluntary intake and growth of Barbarine yearlings fed cactus-based diets.

Four isonitrogenous and isoenergetic diets (D1 to D4) were offered each to 6 Barbarine yearlings for 60 days (summer 1995). On all diets, freshly cut cactus was fed ad libitum in addition to a limited amount of hay (170 g/d). Diets were supplemented respectively with 8 g/d urea (D1), 770 g/d *Atriplex halimus* (D2), 740 g/d *Atriplex nummularia*

(D3), and 65 g/d soya bean meal (D4).

The relatively low intake of cactus and the poor nitrogen content of *Atriplex* sp. was due to the drought during the year of the experiments.

Results showed that cactus-based diets may be supplemented efficiently with *Atriplex nummularia*. Urea and *A. halimus* lead to low growth rates in comparison to soya bean meal or *A. nummularia* supplemented diets.

The voluntary intakes were 694, 844, 858 and 674 g DM per day for diets D1, D2, D3, and D4, respectively. The average daily live weight gains were 55, 58, 74 and 70 for D1, D2, D3 and D4 respectively (table 3).

Such diets, using low inputs of cereals (28% of the diet) and forage (17% of the diet), are recommended to cope with the feed deficiency in arid and semi-arid areas prevailing in North Africa.

Table 3: Feed intake and live weight gains

Diets	D1	D2	D3	D4
Feed intake (g DM/day):				
Cactus	241	252	241	228
Atriplex halimus	0	224.2	0	0
Atriplex nummularia	0	0	225.8	0
Soybean meal	0	0	0	57.6
Barley	308.8	243.6	243.6	243.6
Hay	149.0	142.9	147.5	150.6
Urea	8	0	0	0
Total intake	706.8	862.7	857.9	679.8
Average daily gains (g/day)	55	58	74	70

Spineless Cactus and Acacia

In this example, the widely introduced shrub *Acacia cyanophylla* was used to supplement cactus-based diets. Indeed, *Acacia* is rich in crude protein (about 13% in DM). For this purpose, 4 Barbarine sheep groups

were fed various diets (R00, R21, R22, R23) (table 4). Hay, a scarce and expensive feed, was distributed in a restricted and limited amount.

The intake of *Acacia* was low (250 g DM/day) because of its high content of condensed tannins (7% DM). These tannins are also responsible for the low digestibility of the *Acacia* crude protein.

Table 4: Diets nutritive value

Diets	R00	R21	R22	R23
Feed intake, g DM/day				
Cactus	0	167	246	267
Acacia	241	373	211	177
Diet digestibility, %				
OM	67.7	76.5	73.9	74.6
CP	45.8	49.4	34.8	16.9
CF	62.8	80.5	77.4	79.9
Retained N., g/day	2.77	2.73	0.46	-1.07

With such diets, the energy requirement for maintenance is matched but a large nitrogen deficit remains and they need to be supplemented with an appropriate source of nitrogen.

Integration of Shrubs and Cereal Crop Residues

EXAMPLE 1: Effect of straw supplementation on intake and browsing of *Atriplex nummularia* (old man saltbush) by 'Segurena' ewes, under pen feeding and free grazing conditions (Correal and Sotomayor, 1996)

This example is taken from experiments conducted in Southern Spain (Murcia) where agro-climatic conditions are very similar to those in North Africa.

In the first autumn experiment under pen feeding conditions, dry Seurena ewes were fed for 6 weeks with two *ad libitum* diets (a) old man saltbush browse (mixture of leaves and young twigs) and (b) saltbush

browse and barley straw. At the end of the experiment, the ewes from both feedlots ended up with higher live weights (LW) and better body condition (BC), which suggests that both diets more than met the sheep's maintenance requirements. In the case of the saltbush/straw diet, ewes consumed about 2/3 saltbush and 1/3 straw. Average total intake was higher for the saltbush/straw diet than for the old man saltbush diet (102 and 88 g DM/kg metabolic weight respectively).

A second winter experiment was run with free grazing in a fenced old man saltbush plantation divided into two halves; in one half, a group of ewes had free access to straw and, in the other half, ewes were fed only on old man saltbush shrubs. The experiment finished when the shrubs were completely defoliated. In both subplots, ewes maintained BC and improved LW, but the straw supplement increased by about one-third the number of grazing days obtained from the saltbush/straw subplot compared to those on the saltbush subplot. The straw supplement also reduced by 33% the average diameter of the twigs browsed by ewes. In conclusion, the use of a barley straw supplement can improve the feeding value of old man saltbush plantations.

EXAMPLE 2: Effect of straw supplementation on the *Atriplex halimus* (saltbush) diet consumed by 'Segurena' ewes (Sotomayor and Correal, 1996)

Dry Segurena ewes were fed in pens for 4 weeks in summer with ad libitum amounts of three different diets: (a) saltbush browse (*Atriplex halimus* leaves and young twigs), (b) saltbush browse and barley straw, and (c) barley straw. Leaf and twig intake was measured daily (by difference between the offered and refused saltbush diets), and sheep live weight (LW) and body condition (BC) weekly. Ewes consuming a mixed diet of saltbush and straw ended up with higher LW and better BC, but those consuming only saltbush, increased LW and lost BC; finally, ewes fed with straw, lost LW and BC.

Saltbush leaves contained about three times more crude protein (18.5% CP) and minerals (29.7%) than stems (6.4% CP and 8.7% ash), and stems contained about four times more crude fibre (53.2%) than leaves (13.9% CF). The average leaf:stem ratio was 1.24 for the saltbush

diet, and 2.23 for the saltbush/ straw diet; hence, with the straw supplement, ewes consumed more leaves (richer in CP) than without it and, in the absence of straw, ewes consumed more stems - probably in search of more fibre in an energy deficient diet. In conclusion, the combination of saltbush browse plus barley straw met the sheep's maintenance requirement during summer.

EXAMPLE 3: Spineless cactus (*Opuntia ficus indica*, var. *inermis*) as a supplement for treated straw (Nefzaoui *et al*., 1993)

Research was performed to study the opportunity to use large amounts of cactus (*Opuntia ficus indica*, var. *inermis*) and also to assess the use of non-protein nitrogen from ammonia or urea-treated straw. Six groups of six Barbarine wethers were submitted to diets including cactus ad libitum and two levels (300 and 600 g) of untreated, urea- or ammonia-treated straw.

Cactus voluntary intakes were high (450 g DM) and were not affected when the amount of straw was increased from 300 to 600 g. Diets containing 64% of cactus were well eaten without any digestive disturbance (table 5). Data indicate that it is possible to provide the sheep maintenance requirements for energy from diets based on cactus given ad libitum with 300 g of straw per day. With a high level of straw (600 g/day), it is possible to achieve 1.7 to 1.9 times energy requirements. To cover nitrogen maintenance requirements, straw should be treated. Cacti may be used as a major component of diets containing cereal straws. Non-ammonia nitrogen provided by the treatment of straw is well demonstrated. However, it is necessary to add appropriate supplements in order to overcome the nitrogen deficiency and to give the fibre needed for normal rumen function.

Table 5: Straw supplementation with spineless cactus (Nefzaoui *et al.*, 1993)

Level of straw	300 g/day			600 g/day		
	US	ATS	UTS	US	ATS	UTS
DM INTAKE, g						
Opuntia	445	447	425	432	462	439
Straw	254	242	249	494	466	486
IN VIVO DIGESTIBILITY,%						
OM	67.9	64.0	63.3	66.5	69.8	72.6
CP	41.1	48.0	43.3	45.9	61.0	77.1
CF	37.5	30.5	29.2	46.5	49.2	52.7
N RETAINED	-0.2	-0.2	-0.6	0.8	2.8	3.9

EXAMPLE 4: Supplementation of straw by *Acacia cyanophylla* (Ben Salem and Nefzaoui, 1993)

Previous studies showed that *Acacia* foliage had a relative high crude protein content. Taking into account this characteristic, it was thought that Acacia may be a suitable protein supplement for poor quality diets (straw, natural range lands, etc.). Ben Salem and Nefzaoui (1993) tested the effect of supplementing straw-based diets with graded levels of air-dried *Acacia cyanophylla* Lindl. foliage on digestion in sheep. Results obtained in this study, which are summarised in table 6., failed to support the above suggestion since there was no positive changes in the nutritive value of straw-based diets supplied by *Acacia.* Data on the crude protein digestibility of diets and the levels of ammonia nitrogen in the rumen fluid of sheep were indicative of an inhibition of rumen digestion. The presence of high levels of condensed tannins, which form insoluble complexes with *Acacia* proteins, seems to be the causative factor. Therefore, it was concluded that *Acacia* is less suitable as a protein supplement for poor quality roughages than might be expected from its high content of crude

protein. Research is being carried out in our laboratory to dissociate the tannin-protein complexes of *Acacia* and preliminary results seem to indicate that polyethylene glycol (PEG 4000) had an affinity for Acacia tannins and thus improved the nutritive value (intake, digestibility, rumen fermentation and growth) of Acacia foliage.

Table 6: Effect of Acacia cyanophylla Lindl. foliage supply on intake, digestibility and rumen fermentation parameters in sheep offered straw-based diets (Ben Salem and Nefzaoui, 1993)

	Level of *Acacia* supply (g DM/day)			
	0	75	150	225
Dry matter intake (g/day)				
straw	425b	431b	687a	350b
straw + *Acacia*	425b	506b	837a	515b
Total diet digestibility (%)				
Organic matter	51.6a	40.7b	48.7a	46.1a
Crude protein	-114.1b	5.1a	-4.0a	5.3a
NDF	60.1a	44.8c	56.7a	49.8b
Ruminal fermentation parameters				
NH3-N (mg l-1)	2.74	0.57	2.97	1.17
Total VFA (mmo-1)	60.5c	67.8b	74.2a	65.0bc

a,b,c: Data in the same line with different superscripts differ ($P<0.05$)

Conclusions

We discussed several examples showing that, in arid and semi-arid zones, shrubs, and especially cactus, play a significant role in providing valuable nutrients to small ruminants. In each example, conventional feeds (concentrates, hay or straw) are used in limited amounts because they are scarce and expensive.

Moreover, we recommend the following ideas:
(i) Encourage shrub plantations on private farms instead of communal rangelands. In other words, shrubs must be considered as a part of the production system and as a permanent fodder resource instead of a 'strategic' or 'reserve' fodder to be used only during drought. This option will facilitate the management of shrubs in a sustainable way.
(ii) Avoid planting a single shrub species. This will promote the availability of feeds during all seasons and will help to provide better balanced diets. Cactus can be used all year around and *Acacia* is mainly used during autumn and winter, while *Atriplex* can be exploited during the winter and summer seasons.
(iii) Plantations should be established in alley cropping where barley (the main cereal sown in arid zones) is planted between lines of shrubs. This will help to give better barley yields and will help to make better use of cereal crops. In fact, barley stubble may be grazed directly and supplemented with Atriplex (a protein source) or cactus (energy source).

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