Massey University

Agronomy Department

Palmerston North

New Zealand

Feed value of tagasaste (*Chamaecytisus palmensis*) for goats and preferential browsing activities by goats and sheep in multi-species shrub /pasture conditions.

A Thesis submitted in partial fulfilment of

the requirements for the degree of

Master of Agricultural Science

in Agronomy

By

Rameshwar Singh Pande

1990.

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Abstract

The objective of the thesis work was to investigate the feed value and diet selection of tagasaste foliage vs lucerne hay chaff; browsing activities in mixed conditions of tagasaste shrub/pasture; and the preference ranking for forage shrubs species including tagasaste in multi-shrub/pasture conditions by goats as well as sheep.

1. Two experiments were carried out in The Animal Physiology Unit, Massey University and Grassland Division DSIR, Palmerston North.

A) Indoor experiment: to evaluate DM intake, feed selection, digestibility, chemical compositions of tagasate foliage and lucerne hay.

B) Outdoor experiment: to evaluate browsing activities of goats on mixed conditions of tagasaste shrub and pasture and goat behaviour.

1.1 DM intake, *in - vivo* OMD, *in- vitro* OMD and body weight change were similar for both tagasaste foliage and lucerne hay groups.
DM intakes were 33.37 ± 1.64 (g/kg BW/day) for tagasaste foliage and 26.49 ± 2.22 (g/kg BW/day) for lucerne hay.

In - vivo DMD were 70.42 ± 1.35 % and 66.94 ± 1.35 % for tagasaste and lucerne hay chaff respectively. Similarly, *in- vitro* DMD were 62.48 % vs 66.63 % for tagasaste and lucerne hay group. Tagasaste leaves only were higher in *in - vitro* DMD compared to stems only. *In- vitro* DMD of leaves were 69.29 % whereas for stems were 47.45 %.

Tagasaste foliage and lucerne hay chaff were similar in Nitrogen (3.16 vs 3.21 % DM); NDF (45.89 vs 45.39 % DM); ADL (7.10 vs 6.76 % DM). But ash content in tagasaste foliage was less than half that of lucerne hay (5.18 vs 11.92 % DM).

Goats selected most leafy parts of the tagasaste foliage, which were high in Nitrogen content and digestibility but lower in NDF and lignin than the feed offored. In the feed refusal of tagasaste foliage Nitrogen content was 2.52 % DM; and NDF and ADL were 55.1% and 9.0% respectively. However, such type of selectivity were not distinct while feeding on lucerne hay chaff, possibly due to its homogeneous nature.

During the indoor measurement periods body weight change were 0.026 ± 0.008 (kg/day/kg BW) and 0.036 ± 0.008 (kg/day/kg BW) for tagasaste foliage and lucerne hay group respectively.

1.2 Goats spent more time on browsing on tagasaste foliage than grazing on pasture. Percentage of activities on browsing observations were 36.0 ± 2.08 % compared to 22.2 ± 2.08 % for grazing and 41.7 ± 2.08 % on idling.

Goats browsed tagasaste foliage up to 1.5 m height. Bipedal stance was frequently observed. Goats ate dead bark of tagasaste branches particularly towards the end of the experiment period when there was no more foliage to browse. The use of artificial shelter was rare, instead of that they selected open and relatively dry places for night camping. Overgrazing might be harmful for better performance of tagasaste plants.

Body weight changes in mixed conditions of tagasaste shrub /pasture conditions were higher than in indoor conditions while feeding either on tagasaste foliage or lucerne hay chaff as a sole diet. In shrub/pasture conditions body weight change was 0.133 ± 0.02 (kg/day/kg BW) and 0.122 ± 0.02 (kg/day/kg BW) for the two groups.

2. In the second trial preference for browsing by goats and sheep in multi-shrub species and pasture conditions including tagasaste, preference ranking for shrub species, and overlap of browsing activities between goats and sheep were evaluated in DSIR, Ballantrae Hill Station. The tested species were six leguminous shrubs including tagasaste, three non leguminous shrubs and two erect grass species.

Leguminous species: tagasaste (*Chamaecytisus palmensis* (Christ) Hutch.), broom (*Cytisus scorparius* (L)Link.), tree medic (*Medicago arborea* L.), black locust (*Robinia pseudocacia* L.), gorse (*Ulex europaeus* L.), short spine gorse (*Ulex europaeus*L.).

Non leguminous species: tauhinu (*Cassinia leptophylla* (Frost.F.)R.Br.), ceanothus (*Ceanothus griseus* (Trel.) Mc Minn.), and manuka (*Leptospermum scorparium* J.R.et, G.Frost.).

Erect grass species: toetoe (*Cortaderia fulvida* (Buchan) Zotov.), pampas (*Cortaderia selloana* Schult) Asch.& Graeb.).

2.1 The browsing activities of goats were high compared to sheep. Goats and sheep ranked shrub species differently, but the differences were not extreme. Similarly, proportional utilizations of shrubs were higher in goats compared to sheep. Overlap of browsing activities for shrub species was higher in summer and autumn than in winter.

Goats spent 44.67 ± 1.3 % of activities on browsing compared to 11.56 ± 1.3 % of sheep. Grazing activities between goats and sheep were 48.57 vs 80.49 ± 1.3 % of total observation respectively. Similarly idling activities were 6.76 vs 7.95 ± 1.3 % for goats and sheep respectively. Low idling activities during the two hours record period might be due to the overnight fasting of the animals.

2.2 The most intensively browsed species were tree medic, tagasaste and ceanothus by goats as well as sheep. Among the other species goats preferred gorse and short spine gorse compared to other shrub species while sheep preferred black locust and broom. Less preferred species were pampas, tauhinu, toetoe and manuka. Utilization of these species was higher by goats than by sheep. A comperison between these results and those of Lambert *et al.*, (1989) indicated that there were some difference in estimates of preference made under indoor and outdoor conditions.

The results indicate the potential of common grazing with goats and sheep especially in shrub/pasture conditions, in the absence of shrubs incorporation of tagasaste in goat farming systems could be useful .

Acknowledgements

****

"Life merge into the all prevalent, the eternal;
body turn to ashes.
Mind ! meditate on the eternal spirit;
Remember past deeds.
Minds ! Remember past deeds;
Remember, Mind ! Remember".
- Eksha-upnishad;

Dr Sally Diana Newton is no more with us. Her deeds, her memory remained only ! I met her at the very beginning of this thesis work as one of the supervisor for this thesis project, her enthusiasm, supportiveness and friendliness impressed me deeply in my heart. I would like to express my sincere gratitude and wish to pray for the everlasting peace of her soul !!!

May Peace and Peace and Peace be Everywhere !!!
****

When a tree bears fruit it is not only the branches which involves to produce that fruit, but the whole system of the tree, the soil where it stands and extract nutrients, the air where it breaths and spread its arms, the sun from where it receives warmth and energy, the environment, the whole eco-system contributes to produce that fruit, in the same way this thesis work could never have come to fruition without the support of many people in many ways. However, the following people who deserves individual recognition for their contribution, for which I am deeply indebted !

First of all I would like to express my sincere thank to Director General Dr. Udaya Singh, and the members of the Animal Service Department, Nepal to nominate me under the auspices scholarship of FAO/UNDP in this beautiful country otherwise it would be impossible for me to get such opportunity.

My special thank to Dr Christie Samuel, Chief Technical Adviser, Himalayan Fodder and Pasture Research Net Work, FAO/UNDP for the arrangement of studentship for the first part of this study and for the sincere advice and support.

I am grateful to Prof John Hodgson, the Head of the Department Agronomy and the members for their support and to arrange funding to continue my study; I would like to acknowledge Ministry of External Relation & Trade, New Zealand for the sponsorship during second year period which enabled me to complete this course.

I deeply acknowledge my supervisor Dr Peter David Kemp for his excellent course planning and arrangement throughout my study period, his proper supervision at the start of the first experiment and during the third experiment of this thesis work. I appreciate his supervision, guidance and his valuable suggestions and comments throughout my thesis writing. Thanks for free, frank and friendliness.

I am greatly indebted to my supervisor Prof John Hodgson (HOD, Agronomy) for his support & inspirations, for his patience and genorosity, besides his proper supervision, guidance and critical suggestion throughout my study and this thesis work, I admire him as a real teacher, he deeply impressed me by his personality, by his affectionate behaviour and supportiveness. Thank you to lead me in the world of grazing behaviour of animals.

Besides to contribute in the study of statistics in the lecture room I appreciate Dr I.L.Gordon for his help and suggestions in the statistical analysis of this thesis work.

My thanks to Dr M. A. Choudhary and Dr A. C. P. Chu for their help in my study and for support.

Thank you to all rest of the teaching staff for their contributions in my study; Mr. C. Matthew, Dr. I. Valentine, Mr. P. Matthews, Mr. K. Harrington, and Mr. W. Parker.

I would like to thanks to the members of Animal Science Department; Prof T. N. Barry; Prof S. N. McCutcheon (Head of the Department Animal Science) for their valuable comments and suggestions during my first feeding experiment and to allow me to use the facilities of Animal Physiology Unit and Nutrition Laboratory.

It was great help from Mr. Maurice Thompson (Agricultural & Mechinery Research Centre) and Mr. W. B. Parlane (The Animal Physiology unit) to collect tagasaste foliage and to organise feeding trial, without their help it was difficult to complete my first trial.

I am grateful to the members of the Nutrition Laboratory, Animal Science Department for the analysis of my most of the samples of the first experiment. Thank you very much Miss Rosemary A. Watson for your help and friendly 'Namaste'. My thanks to Mr. D. A. Hamilton especially for his help in *in-vitro* digestibility and Nitrogen determination, it would be impossible for me to complete the chemical analysis without their help.

My thanks to Mr. Dave Sollitt; Mrs. June Cave; Miss Cally McKenzie; Mrs. Colette Gwynne; Mr. Terry Lynch; Mrs. Frith Brown; Mr. Gary Evans; Mr. Brian Thomson for their help and to organise the materials and equipments for this thesis work and in many other ways to support me. My thanks also to all the members of Massey Library and Computer centre.

I am grateful to DSIR, Grassland Division, Palmerston North to allow me to use their experimental block of tagasaste for the second trial. Especially I would like to thank Dr Greg M. Lambert; Mr. Philip Budding; Mr. Roger Redmayne; Mr. Brian Devantier; Mr. Nick Dymock and all the members of DSIR, Grasslands Division, Ballantrae Hill Station for their great help and cooperation during the third experiment period and for the permission to use their shrub nurseries with experimental goats and sheep.

I would like to thank to all my well wishers especially Mrs. Ruth Hodgson and

Dr Ross R. Nelson for their affection, friendship and the concern about my family members.

My especial thank to Mrs. Gladys Durand (Venezuala); and Mr. Thonkey Dukpa (Bhutan) for being a nice friend, and all the Post Grade students of this Agriculture & Horticulture Faculty, whom I fail to mention individually at this moment especially, those who knows my tenderness inside this very rough and tough cocoon.

My sincere thanks to my respectable parents Mr. Purna Singh Pande and Mrs. Devaki Pande, my brother & sisters, and my life partner Mrs. Sumitra (Gyanu) Pande and our love Kricha & Krijuta just for being one of the part of my soul.

Finally, I wish to thank to the supreme power; the almighty God! for whom we are simply a piece of pawn ! just a pawn !!!

Thank you/Kia ora/Dhanyabad !

Rasi Pande.

1990.

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Chapter - 1

Introduction

Shortage of green forage in quantity and quality especially during dry seasons is common in pastoral system throughout the world (Oakes & Skov, 1962; Panday, 1982; Davis, Hunter, 1986). Due to the moisture stress shallow rooted grasses and legumes fail to meet the optimum level of production, so forage species which can tolerate dry conditions and are able to produce high quality feed in adequate quantity are desirable. Deep rooted shrub species which have received little attention until recently are an option for such situations (Skarman, 1977; Davis, Hunter, 1986). Besides providing supplementary feed (Wilson,1969; Everest 1969; NAS, 1977; Skerman, 1977; Van Dyne *et al.*, 1980; Harrington, 1981; Panday, 1982; Radcliffe, 1982; Borens, 1986); browse shrubs also provide shade and shelter to the animals (Davies, 1981; Reid, 1982; Bird *et al.*, 1984; Wills & Sheppard, 1986). Browse also helps to control intestinal parasite as most of the foliage is free from parasitic larvae (Norton, 1985). On the other hand, shrubs are also useful for soil conservation, to maintain agricultural sustainability, and to counteract the green house effect. Plantations of shrubs and trees are an ecologically sound system.

There are more than 100 different species of shrubs and trees which are used as animal feed (Skerman, 1977; Panday, 1982; Ranawana, 1987). Most of these species grown for browse value are suited to warm climates; examples are *Leucaena*, *Gliricidia*, and *Sesbania* (NAS, 1977; Skarman, 1977 Joens, 1979; Chadhokar, 1982). Virtually there are no suitable shrub species for temperate climates. Recent work on tagasaste (*Chamaecytisus palmensis*) especially in New Zealand and in Australia show a promising result in this respects. It is a leguminous shrub. Its Dry Matter (DM) yield, feed value, Nitrogen fixation and importance for soil conservation is as high as other forage shrubs (Radcliffe, 1982; Snook, 1984; Borens 1986; Lambert *et al.*, 1989 abc; Lucas *et al.*, 1990).

Browse can contribute a substantial proportion of the diet for goats, sheep, cattle and deer (Wilson, 1969; Sharma, 1985; Devendra, 1987). Goats have been found to select more browse than sheep or cattle, when offered a range of herbage (Devendra, 1978; Van Dyne *et al.*, 1980; Devendra and Mcleroy, 1982; Smith, 1984; Betteridge and Lambert, 1987). In rangeland conditions browse might contribute up to 80 % of the diet of goats (Devendra & Mcleroy, 1982; Smith, 1984; Van Dyne *et al.*, 1980) and up to 20% in sheep (Van Dyne *et al.*, 1980). Deer also depend heavily on browse and forbs in range conditions (Taylor, 1985). But in conventional farming systems choice of browse is usually limited.

Differences in dietary preferences were demonstrated between goats, sheep and cattle (Arnold, 1981; Van Soest, 1982; Clark *et al.*, 1982; Forbe & Hodgson, 1985; Grant *et al.*, 1985; Lambert & Clark, 1987). Goats are browsers (Devendra, 1978; 1987; Van Soest, 1982), and have been recognised for their ability to control shrubby weeds in New Zealand (Wright, 1927; Rolston, Clark, Betteridge & Lambert, 1985; Radcliffe, 1985; 1986;); Australia (McCarthy, 1985; Mitchell, 1985); U.S.A. (Child, Byington and Hansen, 1985), and in Nepal (Pradhan, 1988).

There is a lack of adequate information on grazing behaviour of goats, especially preference ranking in mixed conditions of pasture/ shrubs, preference for different shrubs, and feed value of browse. Most of the information on goat behaviour and nutrition are translated from sheep data (NRC, 1981; Wilkinson & Stark, 1987). More understanding in this respect is necessary to develop management strategies for goat farming.

The main objectives of this thesis were to study the browsing behaviour of goats compared to sheep, and the feed value, preference and selectivity especially for tagasaste in multi-shrubs pasture condition.

Chapter - 2

Literature review

2.1 *Introduction*

Forage shrubs and trees serve as an important source of feed for domestic as well as wild animals. In the tropics especially browse contributes an important source of feed during the dry season. Among different forage shrub and trees species, leguminous shrubs such as *Leucaena* and *Acacia* are the most widely and popularly used browse shrubs (NAS, 1977; 1979). However, *Leucaena* contains mimosine which is toxic to animals (NAS, 1977;1979; Jones, 1979), and similarly many other browse species contain secondary compounds (Barry & Blaney, 1987). Also, most of these species are suitable for warm climates but relatively few species are adapted to cold climates.

Tagasaste (*Chamaecytisus palmensis*) seems a promising species as it is leguminous and temperate species, produces good quality feed in substatial amounts and there are no side effect in animals fed a sole diet (Poppi, 1982; Borens, 1986).

Goats are browsers (Devendra, 1978; 1987; Van Soest, 1982), and have been recognised for their ability to control shrubby weeds in New Zealand (Wright, 1927; Rolston, Clark, Lambert, 1983; Betteridge & Lambert, 1985; Radcliffe, 1985; 1986), Australia (McCarthy, 1985), U.S.A. (Child *et al.*, 1985), and in Nepal (Pradhan, 1982). There are differences in dietary preference between goats, sheep and cattle

(Arnold,1981; Van Soest, 1982; Clark *et al.*, 1982; Lambert & Clark, 1987).

In this literature review the agronomy of eleven shrubby species, the feed value of browse and the grazing and browsing behaviour of goats and sheep are reviewed.

2.2 *Agronomy of shrub species*

2.2.1 *Leguminous shrubs*

2.2.1.1 *Tagasaste (Chamaecytisus palmensis (Christ) Hutch.)*

Tagasaste is a naturalized leguminous shrub (Davis, 1982; Webb, 1982), categorized as a weed in New Zealand (New Zealand weed and pest control society Inc, 1984).

Tagasaste is found to grow in a wide range of environments, from Mediterranean (e.g. Margaret River, Western Australia) (Snook, 1984) to temperate climates (South Island New Zealand), from low rainfall (less than 300 mm, Australia) (Snook, 1984) to high rainfall (2000 mm, New Zealand) (Sheppard & Bullock, 1986), from sea level & volcanic region (Canary Island Lapalma, Spain) (Webb, 1982) to the altitude of 750 m elevation in New Zealand (Davis, 1982).

A fast growing drought resistance shrub, tagasaste (Bannister, 1986) has foliage yield from 13 to 25 tons DM/ha on a 1000 plants/ha basis (Radcliffe, 1983; Townsend and Radcliffe, 1987; Woodfield and Forde, 1987). Tagasaste can be established either by sowing or drilling seeds or by transplanting saplings (Lyttle and Popay, 1986; Townsend and Radcliffe, 1987).

Tagasaste can grow in a wide variety of soils, except under water logged conditions (Snook, 1962; Dann and Trimmer, 1986). Tagasaste can also tolerate acidic conditions (pH value from 5.1 to 7.5) (Davis, 1982; Palmer, 1984; Townsend and Radcliffe, 1987), which demonstrates its usefulness for plantations in areas that are relatively dry and unfertile for other crops. Tagasaste is relatively free from disease and pests, and is resistant to leaf disease and stem nematodes, but it is susceptible to root rot (*Phytophthora citricola*) especially in wet soil conditions (Palmer, 1984; Macfarlane, 1985; Dann and Trimmer, 1986).

Tagasaste is highly nutritious, palatable, and relished by all classes of stock (Snook 1984; 1986; Borens, 1986; Lambert *et al.*, 1989b; Lucas *et al.*, 1989). However, the feed value of tagasaste is reported as being maintenance (Poppi, 1982; Borens and Poppi, 1985; Borens, 1986). Borens (1986) found that live weight gain by lambs feeding on tagasaste as a sole diet was similar to brown top pasture of summer time. The average live weight gain of lambs consuming tagasaste was 81 gm/day whereas on prairie grass and lucerne it was 151 g/day and 265 g/day respectively. Intake of Digestible Organic Matter (DOMI) was found to be 27 ± 5.1 g/day by sheep in which 72 % DMI was leaves (Borens, 1986).

The digestibility of tagasaste foliage is high (Borens, 1986; Lambert *et al.*, 1989c) (Table 2.1), with an estimated ME value was 10.3 Mj ME/kg DM (Borens, 1986). Tagasaste is a highly nutritious feed. Published data on nutrient content shows that it contains a high level of protein (21.5 %) in its foliage, 17.5 % crude fibre and 5.5 % ash in its foliage. Minerals such as Ca, P, S, Mg, Cu, Mo, in the leaves are found to be quite satisfactory (Table 2.1). No toxicity problems have been reported on animals feeding tagasaste as a sole diet (Poppi, 1982; Borens, 1986).

Table 2.1

Nutritive composition of tagasaste

A) Digestibility of tagasaste foliage

In-vivo DMD	69%	(Borens, 1986)
In- vitro DMD	71%	(Lambert *et al.*, (1989c).
DMD (leaves)	71%	(Borens, 1986).
DMD (barked stem)	26%	(Borens, 1986).
DMD (Bark)	60%	(Borens, 1986).

B) Fibre components in tagasaste (Lambert *et al.*, 1989d).

Constituents	Leaves	Stem	Foliage
NDF %	32.0	63.0	41.0
ADF %	19.0	45.0	27.0
ADL %	6.4	9.8	7.3

Table 2.1 (continued)

C) Chemical composition of tagasaste

	Borens (1986)		Lambert *et al.*,(1989d)	
Plant parts	Leaves	Stem	Leaves	Stem
OM (%DM)	9.60	-	-	-
Nitrogen (N) (%DM)	3.40	0.60	3.00	1.30
Phosphorus (P)(%DM)	0.14	0.07	0.15	0.08
Potassium (K) (%DM)	0.53	0.44	1.10	1.20
Sodium(Na) (%DM)	0.049	0.12	0.03	0.04
Magnesium(Mg) (%DM)	0.26	0.13	0.17	0.09
Calcium (Ca) (%DM)	0.45	0.18	0.42	0.17
Copper (Cu) (mg/kgDM)	0.51	3.41	7.10	4.30
Manganese(Mn) (mg/kgDM)	89.89	46.55	204.00	66.00
Iron (Fe) (mg/kgDM)	45.82	21.35	125.00	102.00
Zinc (Zn) (mg/kgDM)	38.34	30.72	58.00	44.00

Tagasaste is highly relished by goats and sheep, its relative preference value was found higher than broom, manuka, pampas, toe toe and tauhinu by both goats and sheep (Lambert *et al.*, 1989b) (Table 2.2).

Table 2.2

Comparative feed value of foliage and DM yield of different plant species (Sorrce: Lambert *et al.*, 1989 abcd).

	Feed value				Yield		Preference	
Species	N%	NDF	ADF	ADL	Ivt DMD	DM yield	Goats	Sheep
Tagasaste	2.5	41	27	7.3	71	422	66	64
Gorse	1.8	65	48	14.9	54	817	71	65
SS gorse	2.1	63	41	15.7	59	310	68	37
Tree medic	1.7	40	25	7.7	73	79	69	50
Black locust	2.8	51	31	9.4	70	315	48	61
Broom	2.4	49	34	10.0	62	581	18	39
Ceanothus	1.7	36	33	15.1	75	251	47	18
Manuka	1.1	58	42	19.8	56	140	46	18
Tauhinu	1.1	50	34	12.0	68	298	3	5
Pampas	1.2	70	40	6.4	48	677	2	20
Toetoe	1.0	79	46	6.6	48	538	23	21
Pasture	2.5	48	29	3.2	69	422	53	75
Hay	1.8	71	41	4.8	61	-	74	78

DM yield=Forage dry matter (g/m row) annual, at Ballantrae,New Zealand.
Ivt=*In-vitro*.

2.2.1.2 *Gorse (Ulex europaeus L.)*

Gorse is an evergreen leguminous plant. It was estimated that approximately 1 million ha of New Zealand hill country is covered by gorse (Prof J. G. H. White 1990: personal communication). Once established gorse is very difficult to control even by the combined use of mechanical crushing, spraying of phenoxy herbicide and burning (Zabkiewicz, 1976).

Gorse is well adapted to a range of environmental conditions. Being an efficient nitrogen fixing plant, it grows well in low soil fertility conditions. The growth rate of gorse is very fast. It can grow even in acid and infertile soils (Scott *et al.*, 1985; Howe, Barry and Popay, 1988). It can tolerate moisture stress conditions also (Scott *et al.*, 1985). However, it can not tolerate wetland conditions (Grime, *et al.*, 1988). Plants are easy to establish. Gorse is found to grows up to 650 m above sea level (Lee *et al.*, 1986; Grime, Hodgson & Hunt, 1988).

The feeding value of gorse is medium (Scott *et al.*, 1985). Howe, Barry and Popay (1988) found that digestibility of Dry Matter (DMD) ranged from 62.8 % to 64.6 % for sheep and 57.9 % to 65.3 % for goats. Similarly metabolisable energy (ME) was 10.48 (MJ/ kg DM) for sheep and 10.72 (MJ/ kg DM) for goats, whereas voluntary intake was higher for goats than sheep (Howe, Barry and Popay, 1988). Howe *et al.*, (1988) observed that the voluntary intake of DM was 34.7 g DM/kg 0.75 per day for sheep and 61.2 g DM/kg 0.75 per day for goats. As gorse plants mature digestibility starts to decline which is due to increasing levels of lignin and hemicellulose.

Most of the growth of gorse (80 %) occurs in spring (Oct. to Dec.) in New Zealand. In summer (Jan. - Feb.) when plants start hardening the remaining 20 % of growth takes place. During this time gorse needles start to sharpen. Sharpening of gorse needles might restrict voluntary intake and sheep may reject gorse during this period (Howe, Barry and Popay, 1988). DM yield of gorse is high. A 2 m stand of gorse can produce 17 t DM/ha/year in New Zealand conditions (Egunjobi, 1971).

Gorse is high in Nitrogen content (range from 1.6 to 2.9) (Howe *et al.*, 1988) Table 2.3.

Table 2.3

Chemical composition of gorse (Howe, Barry and Popay, 1988)

Dry Matter	%	24.9 - 40.7
Heat of Combustion		
(Mj/kg DM)		20.8 - 21.8
Nitrogen	%	1.6 - 2.9
Cellulose	%	24.5- 27.9
Hemicellulose	%	7.4 - 10.1
Lignin	%	17.1- 20.0
Phosphorus	%	0.07- 0.17
Sulphur	%	0.09- 0.16
Magnesium	%	0.14 - 0.26
Calcium	%	0.25 - 0.43
Sodium	%	0.14 - 0.30
Potassium	%	0.68 - 1.68

2.2.1.3 ***Short spine gorse (Ulex europaeus L.)***

Short spine gorse is a local line of common gorse, developed at Grasslands Division, DSIR, Palmerston North. Plants are shorter in height, densely branched and form a dense canopy compared with common gorse. The spines are softer and shorter than in common gorse.

Short spine gorse is high in Nitrogen content and moderate in digestibility. Lambert *et al.*, (1989d) reported that it contains 2.1 % Nitrogen in its foliage and its DMD value was found 59% (Lambert , *et al.*, (1989c). The DM production of short soine gorse was reported higher than tree medic, manuka, tauhinu and ceanothus (Lambert *et al.*, (1989a). Short spine gorse was highly relished by goats compared to sheep Lambert *et al.*, (1989a) Table 2.2.

2.2.1.4 ***Black locust** (Robinia pseudacacia L.)*

Black locust is a tall tree-like deciduous leguminous plant growing up to 25m -30m height (Reid & Muiller, 1982; Cooper & Johnson,1984; Woodward, 1985).

Its growth rate is very fast. It was observed that within the two growing season it atainded average 1.8m height in Kaikohe, New Zealand (Rumball, 1985). The DM production of black locust was found comperatively higher than short spine gorse, tree medic, and other shrubby non legume (Lambert *et al.*, 1989a).

It is highly protenious feed, its Nitrogen content is comparaytively higher than tagasaste, tree medic and gorse (Lambert *et al.*, 1989b) Table 2.2. The relative preference value of black locust is higher in sheep compared to goats (Lambert *et al.*, 1989b).

It contains large quantities of condensed tannins and toxic glycoside 'Robin' (Steuart, 1964; Cooper & Johnson,1984; Woodward, 1985; Horigome, *et al.*,1988), which might affect animal performance (Barry and Blaney, 1987).

2.2.1.5 ***Tree medic** (Medicago arborea L.)*

Tree medic is a leguminous shrubby plants of Mediterranean origin. It has a good potential for fodder production (Davies, 1985). It is drought and frost tolerant shrub compared to tagasaste (Wills and Sheppard, 1986).

The DM production of tree medic was found to be 1340 kg DM/ha in the first year of planting in Canterbury, South Island compared to 2600 kg/ha for tagasaste, 140kg/ha for Flevo poplar and 160 kg/ha for Matsudana willow (Mcleod 1982). Similarly, Radcliffe (1985) found that DM production from tree medic was 650-750 g/plant in its 2nd season of planting. This production level was lower than tagasaste (2.9 kg/ plant) but was higher than flevo poplar and willow species. Radcliffe (1985) found that N content in tree medic was 3.0 - 4.6 % in leaves and 1.4 - 3.3 % in stems.

The digestibility of tree madic was found comparatively higher than tagasaste, gorse, black locust (Lambert *et al.*, 1989b) Table 2.2. Tree medic cannot tolerate heavy grazing, as it is very palatable to animals (Scott *et al.*, 1985). It can be rapidly browsed out (Sheppard, 1985), so intermittent grazing with long recovery periods is required (Scott *et al.*, 1985; Wills, Sheppard, 1986). Lambert *et al.* (1989b) reported that the relative preference value of tree medic was higher in goats than sheep (Table 2.2).

2.2.1.6 ***Broom*** *(Cytisus scoparius* ***(L.)(Link.)****.*

Broom is a leguminous shrub of 2m height. It has been declared a noxious plants in New Zealand according to Noxious plant Act, 1978 (New Zealand weed and pest control society Inc, 1984). Due to its small leaves and somewhat wiry stems broom is considered unattractive as a food plant (Cooper and Johnson, 1984) and acceptability to animals is low (Scott *et al.*, 1985).

Gebru (1989) reported that the edible forage yield of broom (857 g DM/m^2) was higher than ryegrass/white clover pasture (686g DM/m^2) and was similar to tagasaste (857g DM/m^2) in Canterbury, New Zealand.

Broom is high in Nitrogen content (2.4% N) and digestibility (62%) (Lambert *et al.*, 1989b). Lambert *et al.*, (1989b) reported that preference for broom is relatively higher in sheep compared to goats.

Some species of broom contain the toxic alkaloid 'Cytisine'in their seeds and leaves (Steuart,1964), which thus may be poisonous to man and affect the heart and nervous system (Steuart, 1964; Cooper, Johnson, 1988).

2.2.2 *Non -leguminous Shrubs*

2.2.2.1 *Ceanothus (Ceanothus griseus (Trel.) Mc Minn.)*

Ceanothus is a member of the Rhamnaceae family (Wills and Sheppard, 1986). It originated in North America. It is a shrubby plant that growing up to a height of 2.5 m.- 3 m and has several stout dense and fine stems which gives a form of mound. It can fix Nitrogen through an actinorhizal association.

Ceanothus can tolerate frost and drought having good potential for erosion control, revegetation, shelter and forage (Wills & Sheppard, 1986). It can grow on a wide range of soils except very coarse textured soil. Its growth rate is slow compared to tagasaste (Wills, Sheppard, 1986), and for better establishment inoculation with Nitrogen fixing fungi is recommended (Wills and Sheppard, 1986).

Nitrogen content in ceanothus is reported is 1.7 % (Lambert *et al.*, 1989b) Table 2.2. The relative preference value of ceanothus is higher in goats than in sheep (Lambert *et al.*, 1989b) Table 2.2.

Ceanothus cannot tolerate heavy grazing especially during establishment (Wills and Sheppard, 1986). Its growth rate is medium - fast (Reid and Miller, 1982). The planting good for pollen and nectar for bees, and it is also used for ornamental purpose.

2.2.2.2 ***Manuka (Leptospermum scoparium J.R.et G. Frost.)***

Manuka is a native tree-like shrubby plant that growing up to a height of 3 - 5 m (Reid & Muiller, 1982; Newsome, 1987). It is widely distributed in the North Island up to 1200 m altitude (Atkinson, 1981). Manuka belongs to Myrtaceae family (Wilson, 1978).

It is estimated that approximately 2,910,000 ha of N.Z. land area is covered by manuka dominated scrub. Manuka is also found in associated with kauri and beach forest (Newsome, 1987). Manuka leaves are brown green in colour and contain aromatic glands on the underside of the leaves (Salman, 1986). Leaves of manuka also contain triterpene acids, and ursolic acid acetate (Corbett, McDowall, 1958), and leptospermone alkaloid (Briggs, Penfold & Short, 1938)

Manuka is low in Nitrogen, high in fibre and digestibility is also relatively lower than tagasaste, tree medic, black locust and broom (Lambert *et al.*, 1989b) Table 2.2. The relative preference value for manuka was found higher in goats than sheep (Lambert *et al.*, 1989b) Table 2.2.

2.2.2.3 ***Tauhinu (Cassinia leptophylla (Frost.f.) R.Br.)***

Tahinu is a native shrubby plant of 1-2 metres height, mostly distributed in coastal hill country in New Zealand. It belongs to the Compositae family. Due to its unpalatability to grazing animals and aggressive nature in the coastal regions (Newsome, 1987). It is estimated that tauhinu-dominated scrub land is approximately 39,000 ha total in both

Islands (Newsome, 1987).

Tauhinu is not suitable as a forage shrub, it is low in Nitrogen content (1.1 % N), high in fibre (NDF 50%) and also low in digestibility (48%) (Lambert *et al.*, 1989b) Table 2.2.

2.2.3 *Erect-grass species*

2.2.3.1 *Pampas (Cortaderia selloana (Schult) Asch. and Graeb.)*

Pampas grass is a erect grass species of South American origin, and it belongs to Gramineae family , genus Cortaderia. Pampas grass was used as stock fodder during the early years in New Zealand (Grimmett, 1935). It is widely used as for soil conservation and erosion control and shelter purposes.

Pampas is a tall grass species. Plants grows up to 2.5 m height, with a seed head that grows up to 3-4m high. Within two years it forms a tussock which may be over 1m in diameter at the base (Gadcil *et al.*, 1984). A large quantity of dead material builds up around the tussocks which increases the fire risk.

Pampas is becoming a serious weed problem especially in the forest plantations (Gadcil *et al.*, 1984; Gaskin and Murray, 1988), and has been declared a weed in New Zealand according to the Noxious plants Act,1978 (New Zealand weed and pest control society Inc,1984).

Pampas has long leaf blades, which are covered with tiny hairs. The leaves are stiff and sharp and can wound when touched. It starts flowers from march to late April in New Zealand. Flowers appear in long panicles and are silvery-white, pink or purple-tinted in colour (New Zealand Weed & Pest Control Society, 1984).

Pampas can be established from seedlings. Three to four months old seedling are ready to transplant in permanent sites. It can produce 15 ton DM/ year (Dunlop and Coup, 1951).

Pampas is low in Nitrogen content, high in NDF and low in digestibility, also animal preference is low (Lambert *et al.*, 1989bc) Table 2.2.

2.2.3.2 *Toetoe (Cortaderia fulvida (Buchan.) Zotov.)*

Toetoe grass is a native to New Zealand. It is similar to pampas grass. It grows up to 2.4 m in height and . The leaves are serrated. Inflorecences are much branched and the pencil is up to 60 cm long. This grass is also used for ornamental purposes (Grounds, 1979). Its leaves contain alkaloid gramine (Donaxine) (Brooker, Cambie, & Cooper, 1987).

Toetoe flowers from October (spring) to January (summer), the colour of the flowers are cream-gold. Flowers appears in panicles. Leaves bases are waxy (What's new in Forest Research, 1984).

It can be established by seedling. Three to four months old seedling are ready to transplant in permanent sites. It can produce 15 ton DM/ year (Dunlop and Coup, 1951).

Feed value of toe toe is very low. Its Nitrogen content is low (1% N), high in NDF (79%) and low acceptance (Lambert *et al.*, 1989bcd) Table 2.2.

2.3 ***Feed and nutritive value of browse***

According to Van Soest (1982) browse comprises woody plants, shrubs and trees, and consumption of browse is restricted to leaves, shoots and smaller branches and cambial layers of large accessible branches. Skerman (1977) suggested the inclusion of fruits and pods of plants in browse. Hodgson (1979) defined browsing as the defoliation of the above ground parts of shrubs and trees by animals.

Browse shrubs play an important role in animal feed in domestic as well as wild conditions. Browse serves as a supplementary diet as well as sole diet for grazing animals especially in the tropics during the dry season and in colder regions over the winter. (Everist, 1969; NAS, 1977; 1979; Harrington ,1981; Panday, 1982; Radcliffe, 1983). Skerman (1977) listed more than 84 different species of browse shrubs and trees of tropical regions and mentioned their chemical composition, which shows that browse is generally high in crude protein. Ranawana (1987) reported that out of 200 different plants fed to animals in Sri Lanka, analysis of 30 different species of tree (17) and shrubs (13) contains on an average 180 gm crude protein per kilogram dry matter in tree species and 164 gm CP/kg DM in shrub species. Digestibility was 56 % and 57 % for tree and shrubs respectively.

Lambert *et al.*, (1989cd) analysed nine different shrubs and two erect grass species and found that several shrub species had lower N level than required for a lactating ewe with single lamb and almost all nine shrub species were low in phosphorus status. However, most of the leguminous shrub species contain higher Nitrogen levels than other non leguminous shrubs and trees. For example, Lambert *et al.*, (1989d) determined six legume shrubby species and tree non legume shrubs and reported that on an average shrubby legumes are high in Nitrogen content than shrubby non-legumes; leaves of the shrubby legumes contained 2.8 % N whereas non legume was 1.5% . Similarly stems of the shrubby legumes was high in Nitrogen content than shrubby non- legumes (1.5% vs 0.8%) (Lambert *et al.*, 1989d). Nitrogen % in tagasaste a shrubby legume was found higher than average shrubby legume i.e. 3.0 to 3.7 % (Borens, 1986; Lamert *et al.*, 1989d) Table 2.2.

Yet, the information on feed value of forage shrubs for different species of animals are limited. In New Zealand studies on forage shrubs have started only recently. Most of the forage shrubs are considered as weeds, among these shrubby species tagasaste is becoming more importance.

Studies of the feed value of different forage shrubs and trees indicate that *Leucaena leucocephala* is the most widely and popularly grown shrub species in tropics (NAS, 1977). When leuceana was fed as a sole diet animals were able to maintain their body weight during the experimental period but the *Leucaena* mixed with the other roughage gave excellent results (NAS, 1977; Jones, 1979). However, *Leucaena* contains mimosine and due to its aggressive nature it is becoming a weed in different parts of the world (NAS, 1977; Jones, 1979).

The foliage of browse shrubs is usually low in digestibility (Harrington, 1981; Panday, 1982). Lambert *et al.*, (1989c) reported the digestibility of 9 true shrub species including tagasaste, most of which are either similar or lower in digestibility than browntop dominated hill pasture (Lambert, *et al.*, 1989c).

Leguminous shrubs such as leucaena and tagasaste have high digestible. The digestibility of leucaena ranges from 50.0% to 71 % (Skerman, 1977), and that of tagasaste may be as high as 71% (Borens, 1986; Lambert *et al.*, 1989c).

Most of the shrub species contains secondary compounds (Barry & Blaney, 1987). The presence of secondary compounds such as tannins might reduce availability of protein and affect digestibility (Kumar and Singh, 1984; Jones & Wilson, 1987; McCabe & Barry, 1988). In some browse species such as tagasaste, duodenal Non-Ammonia Nitrogen (NAN) supply was lower than that from temperate pasture, which might be related to decreased live weight gain (Borens, 1986). Borens (1986) observed that approximately 31% of NAN was lost across the stomach when lambs were fed tagasaste *ad-libitum*, in her study nitrogen intake was 1155 mg/kg/w/day and the duodenal NAN flow was 801 mg/kg/w/day. However, there are no ill effects of tagasaste fed as a sole diet (Snook, 1961; Borens, 1986; Borens and Poppi, 1986).

Animal production is also low when shrubs are fed as a sole diet, but they can still be the sole source of feed for animals when herbacious forage is scare (Van Eys *et al.*, 1986).

2.4 ***Grazing and browsing behaviour of goats and sheep***

Defoliation of the above-ground parts of rooted plants in the ground layer of vegetation by animals is defined as grazing whereas browsing is the defoliation of above-ground parts of shrubs and trees (Hodgson, 1979).

When given a choice goats and deer utilize browse more than any other ruminants. When categorizing the behaviour of ruminants, Devendra (1987) grouped goats as browsers and sheep and cattle as grazers. Van Dyne *et al.*, (1980) reviewed the wide range of literature on the basis of published papers, and concluded that the overall contribution of browse is greater in goat diets than in sheep and cattle (Table 2.4).

Table 2.4

Proportions of the major plant groups in the diets of different ruminant species (Van Dyne *et al.*, 1980).

Species	Shrubs	Forbes	Grasses
Cattle	15.0	15.0	70.0
Sheep	20.0	30.0	50.0
Goats	60.0	10.0	30.0
Deers	60.0	30.0	10.0

Goats are more active and exhibit bipedal stance while browsing whereas sheep are more sedentary. Similarly, goats are more selective and are more discerning in their tastes than sheep (Devendra, 1987). Goats have greater tendencies to change their diet according to changing seasons (Huston, 1978; Devendra, 1978; Lu, 1988)). Goats prefer variety in their diet and tolerate bitter taste more than sheep and cattle (Devendra, 1978). They also prefer clean feed and refuse any soiled feed (Devendra and Mcleroy, 1982).

McCabe and Barry (1988) found that voluntary intake on browse shrub (*Salix* spp) was higher in goats than deer and sheep, When McCabe and Barry (1988) ranked the animals according to the preference for browse the DM intake was higher in goats than deer and sheep, but for the standard diet of lucerne hay there was no significant difference between animal species. Similarly Howe, Barry and Popay (1988) observed that voluntary intake of DM was considerably higher in goats than sheep when a chopped gorse (*Ulex europeaus*) diet is offered in housed conditions.

Eye-level feeding is a common foraging posture of goats. By such foraging strategy goats also avoid the risk of infection by parasites which commonly occurs on ground vegetation (Lu, 1988). Many studies showed that they prefer browse more than grazing. Goats can browse foliage up to 2 m in height, and such ability of bipedal stance maximizes the availability of feed within a given area. Goats strip bark and the kill fodder shrubs (Maher, 1945; Hume, 1987).

2.5 *Animal activity of goats and sheep*

2.5.1 ***Grazing time***

Many studies show that ruminant species spend between 4.5 hrs and 14.5 hrs per day in grazing, depending on physiological status of the animals and sward conditions and rate of eating (Jamieson and Hodgson,1979; Arnold, 1981; Hodgson, 1982). However, most of the ruminants spend about one third of the day actually grazing (Arnold, 1981; 1985a Forbes, 1982). Similar feeding time have been reported for goats also (Askin and Turner, 1972). Being browsers, goats spend about 28% of feeding time on grazing and the remain on browsing (Askin and Turner, 1972). Geoffroy (1974) reported that feeding periods are more frequent in goats than sheep. Goats spend more time on diet selection and travel longer distances in search of feed compared to sheep and cattle (Devendra, 1978; Malechek and Provenza, 1981; Lu, 1988).

The ruminants graze mainly during daylight (Dulphy *et al.*, 1980; Arnold, 1985a). Night grazing is common in both tropical and temperate regions (Cowan, 1975; Jamieson and Hodgson, 1979). Out of the total grazing time, there is a nornal periodicity of grazing actvity (Forbes, 1982), animals grazing in four to five occasions during the day (Van Dyne *et al.*, 1980; Hodgson, 1982a). Major grazing activity occurs at dawn, mid-morning, mid-afternoon and again at dusk (Cowan, 1975; Hodgson, 1982a).

2.5.2 ***Ruminating and rest***

Rest as defined here incorporates all behaviour patterns not including locomotion or feeding; animals may therefor be at rest when either standing or lying. Most animals spend more than 50% of their time in a state of rest as defined above, and during the rest period ungulates also ruminate (Arnold, 1985b). Out of the total time spent in rest sheep are observed to spent 56 - 95 % of rest lying (Arnold, 1985b). The time spent resting depends on conditions of grazing, demand of feed and climatic factors. For example in hot days animal prefer to stand rather than lying but in cold days animals prefer lying (Malechek and Smith, 1961). Similarly in housed conditions animals may have more time for rest compared to free ranging animals (Arnold, 1985b). During the 24 hrs goats spend more than one third of their time ruminating. Goats spent 3.5 to 13.0 hrs per dayin rumination in housed conditions (Bell and Lawn, 1957), depending on amount of intake and the type of feed (Lu, 198). However, most of the rumination takes place during night (Bell and Lawn, 1957).

The choice of resting site is influenced by the need for thermoregulation as well as from protection from predator attack (Arnold and Dudzinski, 1978). In farmed conditions sheep usually prefer to use the periphery of the paddock and generally higher ground (Arnold, 1985b).

Goats kept outdoors must have access to shelter at all times. In the abscence of natural shelter, artificial shelter is required. All goats dislike wet weather and their coats provide less protection against wetting then does a sheeps' fleece (Russel and Mowlem, 1988). Goats are also suceptible to heat stress, when depression of feed intake and reduction in production are common (Lu, 1989). Goats also seek shade on very hot days and will make use of shelter in all weathers.

2.6 *Selective behaviour*

2.6.1 *Diet selection*

Grazing animals are selective in nature (Wilson, 1957; Wilson, 1969; 1977; Wilson *et al.*, 1975; Grant & Hodgson, 1980; Arnold, 1981; Van Soest, 1982; Hodgson *et al.*, 1983; Malachek and Provenza, 1983; Provenza *et al.*, 1983; Waggonery & Henkes, 1986; Howe; Barry and Popay, 1988; Lambert *et al.*, 1989b). Diet selection is described as the function of preference between one plant community and another, or some component of the sward rather than another (Hodgson, 1979; Forbes, 1982). In essence selection is preference modified by opportunity. Opportunity arises from a combination of sward and animal factors that determine the accessibility of the sward and its components to the grazing animal (Hodgson,1979; Forbes, 1982).

Diet selection is governed by a complex mixture of factors (Heady, 1964). Grazing animals use the sense of sight, touch and olfaction (taste and smell) in selection of their diets (Arnold, 1981; Hodgson, 1985).

Selectivity is conditioned by two major factors, palatability and preferences (Van Dyne *et al.*, 1980). Palatability refers to the plant characteristics and preference refers to the selection by the animal (Van Dyne *et al.*,1980). Selection influenced by animal preference for plant components and their relative abundance and accessibility (Hodgson, 1982a), and quality (Sheffield, 1983). However, selection is reduced by high grazing pressure, uniformity of sward (Van Soest, 1982); high density of forage (Bedell, 1968) high level of utilization of pasture (Arnold, 1987), and by chopping, wafering, grinding or pelleting the diet (Van Soest, 1982). Still, under the condition of limited intake some degree of selection occurs (Van Soest, 1982). Such preference varies with plant species, plant parts, plant succulence, time of day and other plant as well as animal characteristics (Clary, and Pearson, 1969). Usually more complex plant mixture offer greater opportunity for selection (Jamieson and Hodgson, 1979; Van Soest, 1982). However, hungry animals are less selective (Van Soest, 1982).

Diet selection can be related to variations in size and metabolic rates of animals, and to differences in the structure and size of the mouth parts between animal species (Van Soest, 1982). The largest species select the lowest quality diet but ingest the higher quantity of food (Bell, 1972). Due to narrow muzzle and mobile upper lips, goats can select more nutritious plant parts from low quality and thorny plants (Smith, 1984; Betteridge and Lambert, 1985). Similarly sheep have thin mobile lips whereas cattle have thick,wide lips which are comparatively immobile but a protractile tongue, hence sheep can select preferred components easier than cattle (Van Soest, 1982; Grant *et al.*, 1985).

A high degree of specialization (selectivity) is only adopted when there is a nutritional advantage from specialization (Arnold, 1981), such as high digestibility (green) vs low digestibility (dead) materials (Waghorn and Barry, 1987), low tannin content vs high tannin content (Provenza and Malecheck, 1984), leaf vs stem (Clark *et al.*, 1987)

2.6.2 ***Selectivity between plant parts***

There are structural differences between different parts of the same plant (Minson, 1981); for example, shrubby leaves are more digestible than stems (Borens, 1986). Grazing animals are found to select more leafy materials from heterogeneous swards (Van Dyne *et al.*, 1980; Arnold, 1981; Hodgson and Grant, 1981; Minson, 1981; Lambert, *et al.*, 1989d). Arnold, (1981) mentions that the diet of grazing animals contains higher Nitrogen, phosphorus and gross energy and lower fibre than the herbage.

Lambert *et al.*, (1989cd) reported that both goats and sheep selected more digestible diets than the the forage available in mixed shrub pasture conditions. However, Pfister *et al.*, (1986) observed that when goats and sheep grazed in the coatinga vegetation in

Brazil they selected diets higher in cruid protein (CP) than did sheep. Such selection of nutritious parts can be identified as nutritional wisdom (Arnold, 1981) of grazing animals, but may in some cases simply reflect greater ease of harvesting (Hodgson,1982b).

2.6.3 *Effects of seasonality*

Most of the browse shrubs are consistent in their chemical composition compared to the pasture species. For example tagasaste leaves are retained for about 5-6 months after emergence without major change in digestibility and crude protein content (Borens, 1986), whereas in most of the pasture species (e.g. perennial ryegrass) DM digestibility and estimated M/D value (Mj ME/kg DM) declines as the plant matures (Wilman and Agiegba, 1982). However, effects of seasonality on chemical composition, digestibility and the acceptance of browse by different animal species are distinct. Devendra and Mcloray, (1982) mentioned that the same plants may be consumed at one time and rejected at other times by goats in tropical regions.

The structural differences between plant parts due to maturity and seasonality might be the cause of acceptance or rejection by animal species. For example Howe, Barry and Popay, (1988) observed that sheep freely consumed gorse during spring and summer but during autumn and winter as the gorse needles became very sharp and hard sheep refused to eat them. DM intake, digestibility and M/D value also decreased continuously as plants matured from spring to summer in gorse (Howe, Barry and Popay, 1988). However, Lambert *et al.*, (1989b) observed that forage shrub preferences were not affected by seasons in goats and sheep in housed conditions.

2.6.4 *Effects of secondary compounds*

The presence of secondary compounds also influences selectivity (acceptability) of plants (Freeland & Janzen, 1974; Rosenthal & Janzen, 1979; Barry and Blaney, 1987). Most shrubs and trees contains a range of secondary compounds, which depress animal production (Bulter and Balay, 1973; Barry and Blaney, 1987). Some times these compounds cause toxicity or poisoning (Mc Donald, 1981; Barry and Blaney, 1987).

Many forage shrubs contains condensed tannins and other phenolic compounds, which reduce the availability of protein and fibre digestibility and also reduce the palatability (Kumar and Singh, 1984; Jones and Wilson, 1987). Due to the presence of condensed tannin, the true digestibility of protein in many browse species is less than in herbacious species (Van Soest, 1982; Barry and Blaney, 1987). Tannins are also implicated in low acceptance of some plants by browsing animals (Arnold, 1981). McCabe and Barry (1988) observed that tree willow (*Salix matsudana* X *alba*) and Osier willow (*Salix viviminalis*) both contain condensed tannin in different concentration. Osier willow was high in concentration (i.e. 66gm/kgDM as against 29gm/kgDM in tree willow). The high concentration of tannin in Osier willow was found to associated with 22% lower voluntary intake of digestible DM than that of tree willow in sheep and goats (McCabe and Barry (1988). However, low concentrations of tannin might have, important nutritional implications for ruminants (Jones, 1979). Few shrub species are free from tannin, though these compounds have not been observed in tagasaste (Borens, 1986).

2.7 *Conclusions*

Low levels of animal production in most of the tropics and other drier parts of the world are mainly due to the lack of sufficient quality feed. Browse shrubs and trees can provide quality feed in such situations, especially because leguminous shrubs are high in crude protein and serve as excellent supplementary feed. There are more than 100 different species of shrubs and trees which are used as animal feed. However, most of the shrubby species are low in palatability, low in digestibility and many contain secondary compounds, which are also related to low acceptance by animals. There is lack of information on animal preference between shrub species, selectivity, effect of seasonality and feed value of browse by different animal species. Shrubby forage can be particularly valuable feed for goats year round as goats have greater preferencefor browse compared to sheep or cattle.

Chapter -3

Feed value & preference for browsing on tagasaste (*Chamaecytisus palmensis* L.) by goats.

3.1 *Introduction*

The use of small trees and shrubs as an animal feed particularly during summer drought has increased over the last decades (e.g. Poppi, 1982; Radcliffe,1982; Rumball & Cooper, 1985; Borens, 1986; McCabe & Barry,1988; Lambert *et al.*, 1989 abcd; Pedersen, 1989; and many others). Most of the forage shrubs and trees are low in protein content,digestibility and nutrient content, though some leguminous shrubs such as *Leucaena* are high in nutritive and feed value. However, *Leucaena* also contains a secondary compound, mimosine, which is toxic to animals (NAS, 1977; Jones, 1979). Tagasaste is also a leguminous shrub. It is high in crude protein, digestibility and nutrient content, and has no side effects on animals (Poppi, 1982; Borens, 1986; Borens & Poppi, 1986).

Tagasaste is relished by all kinds of ruminants (Snook, 1984). The feeding value of tagasaste for sheep has been reported (Borens, 1986). Developments of grazing systems with the incorporation of tagasaste could improve animal production by supplying quality feed throughout the season especially for goats, which prefer to browse more than cattle and sheep (Devendra, 1978; Lambert and Clark, 1987), and in drought and rank pasture conditions (Radcliffe, 1983; Sheath *et al.*,1987) for other stock. It would also help to avoid mineral deficiencies which afflict other species (Devendra & Burns, 1983).

In the present study two experiments were conducted in indoor conditions and in field conditions. The objectives were as follows:

3.2 *The objectives*

3.2.1 *Experiment - I: Indoor study*

To evaluate feed intake, feed selection, digestibility and chemical composition of tagasaste foliage and lucerne hay chaff by goats.

3.2.2 *Experiment - II: Field study*

To study browsing activities, animal behaviour and preference for browsing on tagasaste vs grazing on pasture by goats.

3.3 *Materials and Methods*

3.3.1 *Experiment - I: Indoor study*

3.3.1.1 *Experimental Design*

For a feeding trial 12 female Angora cross growing goats were randomly assigned to two forage groups, tagasaste foliage and lucerne hay. There were six goats in each group. The total period of trial was 4.5 weeks from 12/7/88 to 12/8/88, incorporating a three-week acclimatisation period and a measurement period of 10 days. The trial was conducted at the Animal Physiology Unit, Massey University, N.Z.

3.3.1.2 ***Tagasaste foliage***

Tagasaste foliage was harvested from two different sources; naturally grown plants around Massey University, and near Aokautere, and a planted block at DSIR, Grasslands Division, Palmerston North. During the period of acclimatization, foliage was collected from the first source. The plants from the different sources were of different age, size, stage and probably different genotype. At that time most of the plants were in the early flowering stage. However, the most leafy parts and non-flowering branches were collected. During the measurement period tagasaste foliage was collected from the second source. The plants were 2 yrs of age and had previously been trimmed up to 1 m height 4-5 months before the collection. The regrowth foliage were mostly leafy, soft, pliable and vegetative. Pencil - sized branches of 15-40 cm long were harvested three times a week with the help of a sickle (Plate 3.1).

The harvested foliage was loosely packed in thick plastic containers and stored in a cold room at temperature 4°C. The foliage was then chopped into 3-5 cm long units with the help of a guillotine, prior to offering to the goats.

Plate 3.1: Harvesting of tagasaste foliage....

3.3.1.3 ***Lucerne hay***

Chopped lucerne hay was purchased from a commercial firm (Elders Pastoral Company, Palmerston North).

3.3.1.4 ***Animals***

Twelve Angora cross female goats aged 9-10 months of initial body wt. 12.7 ± 0.72 kg were used. The experimental goats were new to feeding trials. They were previously grazing on conventional hill pasture at Ballantrae Hill Station, DSIR, near Woodville. Goats were housed in metabolism crates for approximately 4.5 weeks. At the beginning of the trial all goats were drenched with Neomix at 0.25 g/ goat with 10 ml of fresh water for 5 days for the control of internal parasites. All goats feeding on lucerne hay chaff were supplemented with lucerne hay supplement general mix at 1.0 g/goats on alternate days throughout the trial period. No supplement was given to the tagasaste group. Free access to fresh water was provided all the time in a separate water trough inside the metabolism cages. Individual body weight were taken at weekly intervals prior to morning feeding.

3.3.1.5 ***Level of Feed offered***

During the three weeks acclimatization period,level of feed offered was determined according to the procedures recommended by Commell (1977), but the amount of feed offered was adjusted to 50 % in excess of the previous day's consumption for each individual goat so as to allow a high degree of selectivity of feed.

When the voluntary feed intakes were observed to stabilize after 21 days, daily feed intake and digestibility were measured over the next 10 days. During that period a constant amount of feed was offered for each individual which was estimated by taking the mean of the daily feed intake during the last ten days of the acclimatization period.

3.3.1.6 ***Sampling procedures***

Feed samples were taken daily and stored in a cold room at -9°C. Faeces were collected and weighed and stored similarly. Refusals and spilled feed were collected and mixed for each individual, then 10 % of these refusals were sub sampled and stored as above.

Sub samples of feed, refusals and feces were freeze dried and ground (1 mm screen) prior to laboratory analysis.

3.3.1.7 ***Leaf: stem ratio of tagasaste***

The leaf: stem ratio of tagasaste foliage was 76.53% : 23.47% on the DM basis. The tagasaste foliage was categorized as follows:

Tagasaste foliage - Fresh leaves and stems up to 5mm diameter.

Tagasaste leaves - Leaves and tips up to 2.2 mm diameter.

Tagasaste stems - Stems without leaves between 2.2 mm to 4.7mm diameter.

3.3.1.8 ***Analytical Methods***

Freeze dried samples of feed, refusal and faeces was taken in duplicate for laboratory analysis. Analysis were done in the Nutrition Laboratory, Animal Science

Department, Massey University, N.Z.

The DM percentage of pooled feed samples, refusals, and faeces were determined by drying in a force draught oven at above 80° C for more than 48 hrs. Dry Matter (DM) content of feed, refusals and feces was determined by oven drying of samples at 105°C for 16 hrs. (Harris, 1970). The ash content in these fractions was determined by incinerating at 500° C in a Muffle Furnace for 16 hrs (Harris, 1970). The Nitrogen (N) percentage was determined by Kjeldahl method. The Gross Energy (GE) content of the feeds, refusals and feces was measured by Automatic Bomb Calorimeter (Gallenkamp Auto Bomb, U.K.). Neutral Detergent fibre (NDF), Acid Detergent Fibre (ADF) and Acid Detergent Lignin (ADL) were determined by using Gravimetric fibre determination procedures (Robertson and Van Soest, 1981). Cellulose and Hemicellulose were calculated by subtracting percentage Lignin (ADL) from percentage (ADF). Similarly the Hemicellulose percentage was calculated by subtracting percentage of ADF from percentage of NDF.

In-vivo Dry Matter Digestibility (DMD), *in-vivo* Organic Matter Digestibility (OMD) and *in-vivo* Digestible Organic Matter in Dry Matter (DOMD) of feed samples were calculated according to Geenty and Rattray (1987).

In-vitro digestibility of feed samples were determined according to Roughan and Holland (1977).

3.3.2 *Experiment-II:Field study*

3.3.2.1 *Experimental Design*

Immediately after the indoor feeding trial goats were allowed free choice of pasture and shrubs (tagasaste) for grazing or browsing in the field. The experiment lasted over a two week period from 15/8/88 to 29/8/88, and was conducted in the tagasaste block of DSIR, Grasslands Division, Palmerston North.

3.3.2.2 *Tagasaste block*

The total area of the block was 200 sq.m. Where tagasaste was planted in rows, row to row distance was 2m and plant to plant distance within rows was 1m. There were altogether 612 plants some of which were dying or dead. The plants were about 2 yr of age and previously trimmed up to 1m height 4-5 months prior to start of the experiment. The regrowth foliage was mostly leafy, soft and vegetative(Plate 3.1).

3.3.2.3 *The pasture mass between shrubs*

The pastures between tagasaste shrubs were 90 % Yorkshire fog (*Holcus lanatus*); 7 % white clover (*Trifolium repens*); and minor amounts of perennial ryegrass (*Lolium perenne*); red clover (*Trifolium pretense*) and some broad leaf weeds on dry matter basis. Pasture mass was 3600 kg DM/ha.

3.3.2.4 *Shelter*

Goats are cold sensitive, and natural or artificial shelter may be essential for better performance (McCarthy, 1985; Rumble, 1985). An artificial shelter of approximately 2.5 X 2.0 X 1.5 m (length by breadth by height) were erected during the experiment period for the use of goats as a camping site.

3.3.2.5 *Measurements*

Grazing activities and preferences for browsing/grazing were measured by direct observation of animal behaviour (Hodgson, 1982a). Grazing activities were recorded into three categories viz grazing on pasture, browsing on tagasaste and idling. All activities except grazing or browsing were considered as idling. The grazing activities were recorded using a time interval sampling technique (Hodgson, 1982a) for periods of one hour during daylight. Out of a total of 15 days grazing 8 records were taken. The hours for recording were selected randomly and care was taken to cover the major grazing periods of the day (i.e. early morning and evening) as pointed out by Hodgson (1982a).

Special characteristics of animal behaviour were also recorded whenever possible such as the use of shelter, social activities, bipedal stance, browsing height, regrowth of shrubs after browsing.

The use of shelter was identified by observing faecal pellet distribution and compressed pasture of the camping site.

3.3.2.6 *Body weight change in goats*

All goats were weighed at the beginning and at the end of the trial. The goats were numbered to identify the two categories from the previous trial feeding on tagasaste and lucerne hay, group 'A' and group 'B' respectively.

3.3.2.7 *Statistical analysis*

One-way analysis of variance was carried out for the significance test for the both set of experimental data using Minitab Release 7.2.

3.4 *Results*

3.4.1 *Experiment - 1 :Indoor study*

3.4.1.1 *DM intake and in-vivo digestibility of tagasaste foliage and lucerne hay*

DM intake (DMI) of tagasaste foliage and lucerne hay, *in-vivo* Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD), and Digestible Organic Matter in the Dry Matter (DOMD) of tagasaste foliage and lucerne hay are presented in Table 3.1.

DMI for tagasaste was similar to lucerne hay on the basis of metabolic body weight of goats,(Table- 3.1).

In-vivo DMD and OMD were similar for both feed groups. However, DOMD was significantly higher for tagasaste than lucerne hay ($P<0.05$) (Table 3.1).

Table -3.1

DM intake (DMI) of tagasaste foliage and lucerne hay, *in -vivo* Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD), Digestible Organic Matter in Dry Matter (DOMD) of tagasaste foliage and lucerne hay by goats.

	Tagasaste	Lucerne hay	SE of mean
DMI			
(g/kg Bw/Day)	33.37	26.49	1.97 **
(g/kg Bw .75/day)	61.92	51.12	3.81 ns
In-vivo			
DMD	0.704	0.669	0.01 ns
OMD	0.714	0.686	0.01 ns
DOMD	0.679	0.613	0.01 **

* =Significant at P<0.05; ns= not significant.

3.4.1.2 *In-vitro* ***digestibility of tagasaste foliage and lucerne hay***

In-vitro DMD, OMD and DOMD were also in similar ranges for both feeds (Table 3.2). However, since only duplicate samples were analysed no standard errors are quoted.

Table - 3.2

In-vitro Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD) and Digestible Organic Matter in Dry Matter (DOMD) of tagasaste foliage and lucerne hay by goats fed as a sole diet (on DM basis).

In-vitro	Tagasaste	Lucerne hay
DMD	62.48	66.32
OMD	69.48	71.49
DOMD	61.33	61.32

3.4.1.3 *In-vitro* ***digestibility of tagasaste leaves vs stems***

In -vitro DMD, OMD and DOMD of tagasaste leaves only were higher by at least 16.1 % compared to stems (Table 3.3). Again, the limited number of sample preclude statistical comparison.

Table - 3.3

In-vitro Dry Matter Digestibility (DMD), Organic Matter Digestibility (OMD) and Digestible Organic Matter in Dry Matter (DOMD) of tagasaste leaves vs stems by goats fed as a sole diet (on DM basis).

	Tagasaste	
In-vitro	Leaves	Stems
DMD	69.29	47.45
OMD	74.34	58.19
DOMD	67.21	47.42

3.4.1.4 ***Nutritive composition of tagasaste foliage and lucerne hay***

The nutritive composition of tagasaste foliage and lucerne hay are presented in Table - 3.4.

The feeds were similar in Nitrogen content, NDF, ADF, ADL and GE. However, ash content in tagasaste was half that of the lucerne hay (Table 3.4).

Table - 3.4

Nutritive composition of tagasaste foliage and Lucerne hay (% DM)

	Tagasaste	Lucerne hay
DM (as fed)	26.68	81.61
OM	94.84	88.09
Ash	5.18	11.92
GE(Mj/kg DM)	20.12	18.37
Nitrogen(N)	3.16	3.21
NDF	45.89	45.39
ADF	28.58	29.00
ADL	7.10	6.76
Cellulose	21.48	22.25
Hemicellulose	17.31	16.39

3.4.1.5 *Chemical composition of feed refusals*

Refusals were mixed with spilled feed which was similar to the feed offered, and this could inflate the estimates of nutritive value. Despite this, feed refusals were high in OM, NDF, ADF, ADL compared to feed offered (Table 3.4 and 3.5).

Table - 3.5

Composition of feed refusal of tagasaste and lucerne hay (% DM)

	Tagasaste	Lucerne hay
DM (fresh basis)	33.35	81.53
OM	95.77	88.54
Ash	4.24	11.47
GE(Mj/kg DM)	20.03	18.26
N	2.52	3.15
NDF	55.10	42.86
ADF	35.83	27.63
ADL	9.00	6.47
Cellulose	26.83	21.16
Hemicellulose	19.36	15.24

3.4.1.6 ***Faecal composition***

Faeces were high in Ash, GE, NDF, ADF, ADL and cellulose compared to feed. Hemicellulose was lower in faeces than in feed offered (Table- 3.6). All of these comparisons are restricted to analysis of duplicate samples.

Table -3.6

Chemical composition of faeces of tagasaste and lucerne hay group (%DM)

	Tagasaste	Lucerne hay
DM (fresh basis)	34.56	29.43
Ash	07.91	15.09
GE (Mj/kg DM)	22.09	19.06
N	02.84	02.57
NDF	62.94	60.02
ADF	46.29	44.05
ADL	17.82	16.05
Cellulose	28.48	28.00
Hemicellulose	16.64	15.98

3.4.1.7 ***Body weight Change during indoor measurement period***

Changes in body wt during the measurement period are presented in Table- 3.7. There were no significant differences between feeds in initial weight or weight change.

Table -3.7

Change in body weight in goats (kg).

	Tagasaste	Lucerne hay	SE of mean
Initial	12.17	13.85	0.69 ns
Final	12.53	14.35	0.71 ns
Change	+0.36	+0.50	0.16 ns
Wt. gain (g/day)	26.0	36.00	10.00 ns

3.4.2 *Experiment-II: Field study*

3.4.2.1 *Grazing activities*

The activities of the goats are presented in Table 3.8.

Animal activities were different between the day hours, viz morning (07.0-11.59 am) vs afternoon (12.00 Pm - 6.00 Pm). There were marked differences in the distribution of time between grazing, browsing and idling activities ($P<0.05$).

Table 3.8

Grazing Activities according to time by Goats (% of total time).

Activities	Morning	Afternoon	Overall
Grazing	5.29	39.54	22.25
Browsing	41.99	29.90	36.00
Idling	52.72	30.56	41.75

Std Err (Periods)- 2.08; SE (overall)- 1.9.

3.4.2.2 *Body weight change in field condition*

Body weight changes are presented in Table -3.9.

Daily body weight gain in the field conditions was similar for both group 'A' (tagasaste fed) and 'B' (lucerne hay fed) in the previous indoor trial (Table 3.9).

Table - 3.9

Body weight change during the measurement periods in goats (Kg) group 'A' (tagasaste fed) and 'B' (lucerne hay fed) in indoor trial.

	Group 'A'	Group'B'	SE of mean
Initial body wt.	12.86	14.23	0.69 ns
Final body wt.	14.85	16.85	0.82 ns
Change in Body wt.	1.99	1.83	0.27 ns
Wt. gain (g/day)	133.0	122.0	0.02 ns

3.5 *Discussion*

3.5.1 *Feed & nutritive value of tagasaste foliage and lucerne hay*

Variation in the nutrient content and internal structure of plant material highly influence the amount of consumption (Hodgson,1982b). Intakes were similar despite much higher moisture content of tagasaste in the present trial. The amount of feed an animal voluntarily consumes and the digestibility are the main determinants of feed value (Raymond, 1969; Ulytt, 1973; 1978; Hodgson,1982b; Holmes, 1987). On this basis the feed value of tagasaste is similar to lucerne hay chaff. Intakes of the two feeds were similar at similar digestibility, indicating no aversive constituents limiting intake of tagasaste (Raymond, 1969).

The intakes of DM by the goats were similar to other browse feeds reported by McCabe and Barry (1988); Howe; Barry and Popay (1988) on willow and gorse respectively. However, Devendra (1987) reported that in wet zones dairy goats may consume feed up to the 6% of their body weight.

In-vivo DOMD was significantly higher in tagasaste foliage than lucerne hay although levels of organic matter and dry matter digestibility, determined seperately, did not differ significantly (Table 3.1). Leaves of tagasaste foliage were higher in DMD, than stem (Table 3.3). Similarly, OMD and DOMD were also higher in leaves than stems. Similar results were reported by Borens (1986).

Tagasaste foliage and lucerne hay were similar in nutritive composition. GE, N,NDF, ADF,ADL and cellulose & hemicellulose contents were similar (Table 3.5). The estimates of nutritive value for tagasaste were similar to the result reported by Borens,(1986).

The foliage of most browse shrubs and trees is usually low in digestibility, and high in fibre content (Wilson, 1969; NAS, 1977; Skerman, 1977; Harrington, 1981; Panday, 1982). However, some leguminous shrubs such as *Leucaena* is high in protein content and digestibility (NAS, 1977; 1979; Jones, 1979). Digestibility and Nitrogen content of tagasaste was also compatible with that of other shrubs (Appendix 3.1). Similar composition of tagasaste was reported by Borens, (1986); Borens & Poppi,(1986).

3.5.2 *Feed selection*

Diet selection is a function of preference for some plant component or for a sample of herbage rather than others, modified by the opportunity for selection (Hodgson, 1979). The present form of diet was heterogeneous in the case of tagasaste foliage, whereas the lucerne hay chaff was homogeneous in nature. Thus the opportunity for selection was higher in the case of tagasaste foliage compared to lucerne hay chaff.

The level of feed offered might influences selectivity. Animals might be forced to eat woody plant tissues in an indoor trial which can be avoided in field conditions;

probably the restricted amount of feed offered in indoor conditions might result in low and biased feed value. So to allow high level of intake and selectivity in the present trial the feed offered was 50% over the mean daily consumption for each individual goat.

During the feeding trial goats were observed to select more leafy parts from the tagasaste foliage. The leafy parts were high in digestibility compared to stems (Table-3.2). Van Soest (1988) comments that diverse nutritional quality of plant fractions has been important in the evaluation of selective feeders. Such selective feeding in indoor conditions was also reported by Ademosun *et al.*,(1985) for West African Dwarf goats feeding on Cynoden hay.

It was observed during the acclimatization period that when feed offered was less than satiety the animals consumed all offered feed, even pencil sized sections of chopped stem of tagasaste. But when feed offer was increased over 100 % of the previous days consumption the goats selected most of the leafy parts of tagasaste foliage. It was also observed that flowers and buds of tagasaste were avoided. Possibly because they were smaller in size due to chaffing process, and comparatively round shaped, the flowers and buds settled on the bottom of the feed trough. Alternatively, the goats may have deliberately avoided the reproductive parts of the tagasaste due to the presence of some phenolic compounds. This could not be confirmed in the present trial.

The difference between diet and sward composition can be defined as selection (Hodgson, 1979; 1986), and a similar interpretation can be applied to indoor feeding also. The differences between the chemical analyses of tagasaste foliage offered and refusals confirmed that goats were highly selective while feeding on browse materials. Refusals of tagasaste were lower in Nitrogen, ash & high in ADF, NDF, ADL and cellulose & hemicellulose, than the feed offered, in agreement with Van Soest (1988) that selective goats eat the less lignified tissue. The fact that refusals were mixed with spilled feed would serve to limit the magnitude of this contrast. The refusals of tagasaste foliage were mostly stemmy material but in case of lucerne hay the refusals were mostly fine materials. However, no strict statistical comparison between feed and refusals was possible because only duplicate samples were analysed.

3.5.3 ***Browsing activities***

The main grazing activity in most animals occurs between dawn and dusk (Hodgson, 1982a; McLeod and Smith, 1989). Also for goats, grazing (including browsing) is a predominant daylight activity (Askins and Turner, 1972; Arnold and Dudzinski, 1978), so recording during of animal activity during night time is ignored in the present study. Most of the ruminant species spend 50 % of their time resting (Arnold, 1985). The present result of idling activity of goats was overall similar. The feeding activities of goats (Table 3.8) were similar to sheep grazing on temperate swards, where time spent feeding by sheep ranged from 20.83 to 56.25 % of total activities based on 24 hrs record period (Hodgson 1982a; 1986).

Goats prefer browse. Overall browsing activities were higher than grazing in the present study (Table 3.7). Owen-Smith and Cooper (1987) also reported that goats spent 45% of the feeding time browsing in the rangland situations in South African

Savanna.

The ratio of grazing to browsing was 38:62 in the present trial. Coppock, Ellis & Swift (1986) observed that diet composition of goats was 36% herbaceous and 64% foliage of shrubs and trees in free ranging conditions in arid north Western Kenya.

There was a significant difference between morning and afternoon feeding activities (Table 3.8). During the morning period browsing activity was higher than grazing. Low grazing activities during morning may have been due to the wet conditions of pasture, as grazing activity may be influenced by sward condition and climatic variations (Hodgson,1982a).

3.5.4 *Goat behaviour*

Generally it is considered that goats prefer browse only, when the availability of pasture is low (Devendra,1978). In this study the availability of pasture mass was high (3600 kg DM/ha). The dominant species was Yorkshire fog (90 % on DM basis). Yorkshire fog is relatively unpalatable due to its hairiness and it tends to be avoided by sheep when other palatable grasses are available (Basnyat, 1957; Cameron,1979).

Goats have the ability to stand on their hind legs and can browse the top branches of shrubs up to 2m height (Devendra, 1978; Smith, 1984). In this trial similar ability of goats were observed frequently. They browsed up to the height of 1.5 m of tagasaste foliage, due to small body size of the goats and and there was little foliage beyond this height.

Goats are well known to kill plants by debarking, nibbling and by breaking the branches of shrubs/small trees (Devendra, 1978; 1980; Radcliffe, 1986; Johns & Macgibbon, 1986). In the present trial goats were observed to eat bark of the dead tagasaste branches only (Plate 3.2). They did not debark live plants. However, such kinds of debarking activities were observed only towards the end of the trial period when al most all accessible foliage was browsed.

Regrowth after the trial period was observed to be very slow.New growth started to commence only after 4 - 5 months. A possible reason for the slow recovery of plants may be due to overgrazing. Goats browsed accessible foliage of tagasaste within a very short period. Before the goats were moved out of the tagasaste block the plants were totally bare of leaves.

Goats are cold sensitive (McCarthy, 1985; Rumble, 1985). Natural or artificial shelter may be essential for better health. However, during the trial period, the use of the shed for night camping was not common. Goats selected either an open places of the paddock or raised places along the fence which were relatively dry and open.

Goats were always together .They were always aware of the activities of the others.Getting up in the morning, camping for the night and feeding activities were group affairs. However, during feeding browsing or grazing or idling was an personal choice. There was no dominant leader in the group. All the experimental animals were yearling females.

Plate 3:2 Debarked dead branches of tagasaste plant by goats

3.5.5 *Body weight change*

Goats do not thrive well on a single type of diet for any length of time (Devendra, 1978). In the indoor study the goats lost body weight during the first two weeks; later they started to recover the lost body weight. The body weight gain of goats during the measurement periods were similar for both feed groups. Van Eyes *et al.* (1986) reported similar body weight gains by growing goats fed on napier grass supplemented with browse foliage such as *Gliricidia*, *Leucaena*, *Sesbania* species. However, McGowan, Robinson, Moate, (1988) also reported that during the 13 days feeding trial both groups of sheep feeding on a sole diet of tagasaste and cocksfoot pasture lost live weight.

In the field conditions body weight gain was higher than in the indoor feeding trial (Table 3.9). It is not clear whether this difference reflects the limiting conditions of crate feeding or the value of the mixed diet of grass and browse materials.

3.6 *Conclusions*

Intake, digestibility and body weight change in goats feeding on tagasaste foliage as a sole diet was similar to lucerne hay.

Tagasaste leaves were high in *in-vitro* digestibility compared to stems. Chemical composition of tagasaste was similar to lucerne hay in N and fibre content but lower in ash.

Goats consumed most leafy parts of tagasaste which were high in digestibility and N content but low in fibre compared to feed offered, and they show a greater preference for browsing on tagasaste compared to grazing on pasture.

Chapter - 4

Preference ranking and browsing activities of goats and sheep for forage shrub species including tagasaste (Chamaecytisus palmensis L.).

4.1 *Introduction*

During grazing, animals are continuously discriminating between alternative choices of vegetation and location for each bite (Hodgson, 1986). Such selectivity is usually greater under range conditions and maximal in browsing conditions (Van Soest, 1982).

The degree of discrimination exerted by animals between swards or sward components, either in the field or in feeding trials, can be described as preference (Hodgson, 1979). Preferences for food plants vary according to animal species in sown pasture conditions (Grant & Hodgson, 1980), or in browse conditions (Wilson, 1957; Wilson, 1969; 1977; Wilson *et al.*, 1975; Malachek and Provenza, 1983; Provenza *et al.*, 1983; Waggonery & Henkes, 1986; Howe, Barry and Popay, 1988; Lambert *et al.*, 1989b). There are greater preferences for some browse species than others (Wilson *et al.*, 1975; 1977; Lambert and Clark, 1987; Lambert *et al.*, 1988b). Goats are more efficient utilizers of browse than sheep (Van Soest, 1982; Devendra, 1983).

The literature on differences in diet selection by different animal species in different seasons is scant (Grant *et al.*, 1985), especially in mixed conditions of pasture/shrubs.

Preferences, selectivity and ranking of browse species by goats and sheep were reported by Lambert *et al.*, (1989b) using paired combinations of chopped forages in housed conditions. Preference ranking of shrub species may vary in between housed and field conditions and method used.

In the present experiment animal activities were studied by direct observations using the time interval technique (Hodgson, 1982a). The main objectives of this experiment were to study the browsing activity and preferences for browse species by goats and sheep in multi-species shrubs and pasture conditions.

4.2 ***Materials and Methods***

4.2.1 ***Location***

The experiment was carried out at the Hill Country Research Station, Grasslands Division, DSIR, Ballantrae, N. Z. Observations took place at intervals over a year, from the 3rd week of Feb. 1989 to the end of December 1989. The ecological characteristics of the site were as follows:

Altitude of Experiment site - 150 m a.s.l.

Slope - 17 - 19 °,

Aspect - South,

Rainfall - 1200 mm/annum,

Temperature - 12.2°C (average),

Soil type - Raumati silt loam (Lambert *et al.*, 1989a).

4.2.2 ***Experimental Nurseries***

Two established shrub nursery sites were used for this experiment. The area of each experimental site was 600 sq m. (30 m X 20 m). Individual shrub species were planted in single rows 5 m long. Row to row distance was 5 m. There were eleven different species, six species were leguminous shrubs including tagasaste, three non leguminous shrubs and two erect grass species (Table 4.1).

Three species (short spine gorse, black locust and ceanothus) appeared only once in each site. The remaining eight shrub species were replicated three times in each site. The original planting distance for each replication was 40 cm, 65 cm and 90 cm from plant to plant. Species of shrubs were randomized within the sites. Altogether there were three rows of nine columns in each site. The shrubs were three to four years of age and grown in a hedge like structure. The number of plants per row are presented in Appendices 4.1. The botanical names of shrub species were followed as Webb *et al.*, (1988).

Table 4.1

Species used in Experiments

I.Leguminous	
Tagasaste	(*Chamaecytisus palmensis* (Christ) Hutch.)
Broom	(*Cytisus scorparius* (L) Link.)
Tree medic	(*Medicago arborea* L.)
Black locust	(*Robinia pseudocacia* L.)
Gorse	(*Ulex europaeus* L.)
Short spine Gorse	(*Ulex europaeus* L.)
II.Non-leguminous	
Tauhinu	(*Cassinia leptophylla* (Frost.F.) R. Br.)
Ceanothus	(*Ceanothus griseus* (Trel.) Mc Minn.)
Manuka	(*Leptospermum scorparium* J.R.et, G.Frost.)
III.Erect grass	
Toetoe	(*Cortaderia fulvida* (Buchan) Zotov.)
Pampas	(*Cortaderia selloana* Schult) Asch.& Graeb.)

4.2.3 ***Pasture in between shrub rows***

The pasture between the shrubs was a mixture of perennial grasses and legumes. Major species were browntop (*Agrostis capillaris* L.), crested dogstail (*Cynosurus cristatus* L.), cocksfoot (*Dactylis glomerata*) and perennial ryegrass (*Lolium perenne* L.), Yorkshire fog (*Holcus spp*) and white clover (*Trifolium repens* L.) and weeds were present in small proportions.

4.2.4 ***Animals***

Six Angora cross female goats and six pure Romney female sheep were used. The age of the animals was 17 month at the start of the experiment for both species. Mean body weight was 18.20 ± 0.4 kg and 43.45 ± 1.1 kg for goats and sheep respectively.

The animals were fasted overnight in an adjacent shearing shed prior to each observation period to encourage feeding. After each grazing period the experimental animals were kept together in the same holding paddock until the next observation.

Before the start of the experiment, the animals were trained in a third nursery site with the same replications of shrub species.

4.2.5 ***Procedures***

Harvesting dates were arranged in a sequence at approximately 4 week intervals between 22 Feb and 22 June 1989; the last harvest was carried out on 24, December 1989. Harvesting dates were scheduled to cover three major seasons summer, autumn and winter (Table 4.2). During the year 1989 commencement of spring was late, so spring harvest was ignored. Some of the experimental animals died over winter, so three each of the goats and sheep were new at the last harvest. Each site of the shrub nurseries was used for each animal species in an alternate manner. Harvesting schedules and allocation of animal species according to sites and harvest dates are presented in (Table- 4.2).

Table - 4.2

Harvesting Schedule

Harvest Period	Date	Site-1	Site-2	Seasons
1	22/2/89	Sheep	Goats	Summer
2	23/3/89	Goats	Sheep	Autumn
3	27/4/89	Sheep	Goats	Autumn
4	23/5/89	Sheep	Goats	Winter
5	22/6/89	Goats	Sheep	Winter
6	24/11/89	Goats	Sheep	Summer

The goats and sheep were allowed a free choice of all plant species in their allocated site over the same two hours at each observation. The observation time from 10.00 to 12.00 hr in each period. Each replication of shrubs was assigned an identification number ranging from 1- 27 for each site. The period of observation was restricted to two hours on each occcasion in order to limit defoliation effects on individual species.

Animal activities (Hodgson, 1982a) were recorded in the three categories of browsing, grazing and idling . The terms browsing and grazing were used as defined by Hodgson (1979). All non-feeding activities were categorized as idling.

The locations of browsing by each animal species were recorded using 'interval sampling techniques' as recommended by Hodgson (1982a). The average frequency of observations was approximately every two minutes. The total number of observations ranged from 49 to 61 per observation period.

A shearing shed about 200m distant from the experimental site was used as the observation post so as to minimize the influence of the observer on animal activities (Jamieson & Hodgson, 1979). For a clear view a standard sized binocular 10 X 50 magnification was used to watch the animal activities as prescribed by Hodgson, (1982a).

Immediately after each harvest period the intensity of defoliation was monitored by counting the number and noting the location of bites taken from each plant in each row. The intensity of defoliation (BRPT) of the plant parts was assumed to be similar (proportional) for all shrub species.

4.2.6 *Measurements*

4.2.6.1 ***Relative Abundance value of forage shrub species.***

Number of plants, length of row, spread (width) of branches and mean height of the plants per replicate was measured. Each replication of the shrub plants was ranked visually for the density of the foliage from 1 - 10 score (lowest to highest) respectively. These parameters (length, width, height and density score) were used to estimate the relative abundance value for each replication of individual shrub species (Appendix 4.1).

4.2.6.2 ***Morphological characteristics of shrub species***

The morphological status of each individual shrub species on the basis of each replication was characterized as vegetative or reproductive prior to each harvesting period (Appendix 4.2).

4.2.6.3 ***Proportional utilization of shrub species***

There are many measures available to calculate the level of utilization of resources or 'niche breadth', such as:

1) Simpson index (Bn) by Levins (1968),

2) Hurlbert (B') (1978), and,

3) Czekanowski's index or Proportional Similarity Index (PS) (Feinsinger *et al.*, 1981).

Plate 4.1: A view of experimental nursery

The Proportional Similarity Index (PS) of Feinsinger *et al.*, (1981) gave the best distribution of utilization (Appendix 4.4), and is used here.

$$PS = 1-0.5 \sum_i | Pi - Qi| \text{ Or, } PS= \sum \min(pi,qi)$$

Where;

Pi = Proportion of observations on browsing for species i;

Qi = Proportion of abundance for the same species.

The similarity in the proportion of total browsing activity spent on any browse species by goats and sheep, for the first harvest date, was compared by using the Proportional Similarity Index (PS Index) or Czekanowski's index (Feinsinger *et al.*, 1981) with other equations (Appendix 4.3).

4.2.6.4 ***Preference index for shrub species***

The initial estimate of preference across species was based on the total number of observations of browsing for each species within an observation period. The preferences for individual shrub species by goats and sheep were then adjusted on the basis of abundance to derive a browsing preference index.

There are several numerical methods or indices reported for determining preference such as:

1) Electivity index by Ivelev (1961),

2) The simple ratio Van Dyne and Heady (1965),

3) The natural logarithm of Selection Ratio (Skiles, 1984),

4) Modified electivity index or Ivelev Index by Skiles (1984),

5) The Relative preference index or Selection Ratio Hodgson (1979); Hodgson and Grant (1981); Loehle & Rittenhouse (1982); Jung, Bennett and Sahlu (1989).

Most of these equations give similar orders of preference, though ranges of value and neutrality values may differ between them (Appendix 4.4). Also, the above indices may include available species which are never consumed by animals. After the examination of alternative expressions of preference index in Appendix 4.4, the following index is preferred for examination of browsing preference in this study.

$$Bp = (Ni/Ai)/(\Sigma NjAj)$$

Where;

Bp = Browsing preference index;

Ni = Proportion of observations on browsing activities for species 'i',

Ai = Proportion of abundance of browse for the same species.

NjAj = Products of (Ni/Ai).

4.2.6.5 ***Overlap of browsing activities***

To measure the overlap in browsing habit of goats and sheep the coefficient ($C\mu$) was calculated using the Morisita Index quoted by (Horn, 1966) (Appendix 4.3). The index ranges from 0 (no overlap) to 1 (identical diets).

$$C\mu = \frac{2 \sum_{i=1} XiYi}{\sum^{n}_{i=1} Xi^2 + \sum^{n}_{i=1} Yi^2}$$

Where;

$C\mu$ = Overlap coefficient;

Xi = Proportions of observations on browsing by animal species X for shrub species 'i';

Yi = Proportions of observations on browsing by animal species Y for shrub species 'i';.

4.3 ***Statistical analysis***

The animal activities browsing, grazing and idling within and between animal species, and the browsing activities (PREF), and intensity of defoliation (BRPT) within animal species and seasons were analysed by analysis of variance using SAS, General Linear model, 1987.

The mean coefficients of proportional utilization of shrubs were compared by T test for goats and sheep using Minitab Release 7.1.

The Preference indices of browsing activities were compared by analysis of variance using SAS General Linear Model, 1987.

4.4 *Results*

4.4.1 *Animal activities*

The proportion of total observations of animal activities that goats and sheep spent browsing and grazing differed significantly ($P<0.01$). Goats were observed to browse more frequently then sheep, whereas sheep were observed to graze more frequently than goats. Idling activity was significantly less than either browsing or grazing for both groups of animal, but it did not differ significantly between goats and sheep (Table -4.3). There was no significant effect of season on these observations (Appendix 4.5).

Table - 4.3

The percentage of observations of animal activity in the categories of browsing, grazing and idling. Percentages are the means for all harvest dates.

Activity	Goat	Sheep
Browsing	44.67 a	11.56 b
Grazing	48.57 a	80.49 b
Idling	6.76 ns	7.95 ns

Standard Error of the mean within table: ± 1.3.

Subscripts indicate significant differences between means within rows.

4.4.2 *Proportional utilization of shrubs*

The mean proportional utilization of shrubs differed significantly between goats and sheep ($P<0.001$). The overall mean was 0.394 ± 0.02; and 0.187 ± 0.02 for goats and sheep respectively. There was no season difference in proportional utilization by either animal species Table - 4.4.

Table -4.4

Proportional utilization of browse shrubs by goats and sheep in different harvest periods.

		Animal species	
Season	Period	Goats	Sheep
Summer	1	0.347	0.245
Autumn	2	0.449	0.199
Autumn	3	0.359	0.179
Winter	4	0.357	0.180
Winter	5	0.417	0.195
Summer	6	0.433	0.123
Mean		0.394	0.187
SE		± 0.02	± 0.02 ***

4.4.3 *Browsing activities*

The browsing activity of goats and sheep are presented in three categories:

1) Distribution of browsing activity (PREF) in relation to the available replicates of plant species (i.e. partially corrected for browse abundance),

2) Defoliation of plant parts (BRPT) (partially corrected for browse abundance), and

3) Preference Index for shrub species on the basis of abundance (fully corrected for variations in abundance).

4.4.3.1 *Distribution of browsing activity (PREF)*

The distribution of browsing activity across shrub species within seasons for each animal species is shown in Table 4.5. The variance for the unreplicated species could not be estimated but was assumed to be the same as for replicated species (e.g. replicated species n=6, and for unreplicated species n=2 for each harvest season) (Table 4.5). The Table 4.5 represents the mean of the browsing activity in relation to the available replicates.

The main effect of animal species (ANID) and season (SEA) were not significant, but plant species (SPID) differences were highly significant ($P<0.001$). There were significant first-order interactions SPID X ANID ($P<0.001$) and SPID X SEA ($P<0.001$), and the second-order interaction SPID X ANID X SEA was also significant ($P<0.001$) (Table 4.5 and, Appendix 4.6).

Overall the intensity of browsing was greater for black locust, short spine gorse, ceanothus, tree medic, tagasaste, gorse and broom than for the other species by both goats and sheep (Table 4.5). Short spine gorse was browsed more intensively by goats than any other species when compared over seasons, whereas sheep browsed black locust more intensively than any other species over all seasons (Table 4.5).

The intensity of browsing on tagasaste was moderate by both animal species.

Some of the available species were not browsed at all (e.g. pampas by sheep in all seasons, and tauhinu in summer by both goats and sheep) and are represented by zero values in Table 4.5.

Table 4.5

Effect of season and animal species on the distribution of total browsing activity (PREF) by goat and sheep.(Overall Ranking in parenthesis).

Replicated	Summer		Autumn		Winter		Overall	
Species	Goat	Sheep	Goat	Sheep	Goat	Sheep	Goat	Sheep
Broom	3.53	4.43	2.85	6.21	0.24	1.79	2.21 (7)	4.15(6)
Gorse	6.53	1.28	4.07	2.56	4.26	2.38	4.95 (6)	2.07(7)
Manuka	0.46	0.00	0.62	0.31	0.14	0.00	0.40 (8)	0.10(10)
Pampas	0.00	0.00	0.20	0.00	0.00	0.00	0.07 (10)	0.00(0)
Tagasaste	5.22	4.69	5.15	8.04	7.10	6.80	5.82 (5)	6.51(4)
Tauhinu	0.00	0.00	0.09	1.25	0.14	0.00	0.07 (10)	0.42(9)
Toetoe	0.61	0.43	0.00	1.75	0.00	0.39	0.20 (9)	0.86(8)
Tr medic	5.57	6.78	9.69	6.43	10.42	8.33	8.56 (4)	7.18(3)
Unreplicated$								
Ceanothus	8.05	2.37	9.31	2.17	10.12	26.43	9.16 (3)	10.32(2)
Bl Locust	22.87	49.75	19.67	29.81	2.38	11.43	14.97 (2)	30.33(1)
S S gorse	10.30	2.17	23.93	0.92	43.45	9.52	25.89 (1)	4.21(5)

Standard Error of the mean (Season): ± 1.85; (Overall): ± 1.07.

$ Standard error of the mean for unreplicated means assumed to be the same as for replicated me

4.4.3.2 *Defoliation of plant parts (BRPT)*

The number of defoliations of plant parts (BRPT) across shrub species within seasons for each ai shown in Table 4.6. The variance for the unreplicated species could not be estimated but was aş be same as for replicated species. Again number of observation for replicated and unreplicated sł as mentioned in section 4.4.2.1.

The main effect of animal species (ANID) was significant (P<0.05), but season (SEA) was (P<0.05), however, plant species (SPID) differences were highly significant (P<0.001). Th(significant first-order interactions SPID X ANID (P<0.001) and SPID X SEA (P<0.001), and tł interaction SPID X ANID X SEA was also highly significant (P<0.001) (Table 4.6 and, Appendi

The number of defoliations was highest in short spine gorse, black locust and tree medic by go Species such as ceanothus and tagasaste were only moderately defoliated by goats (Table 4.6) defoliated black locust but they also defoliated to a lesser extent, ceanothus, tree medic, sh(broom and tagasaste (Table 4.6).

There were no recorded defoliations on some of the available species such as manuka, tauhir toetoe by both goats and sheep in any season; they are presented by zero in Table 4.6.

Table 4.6

Intensity of defoliation (number of bites of plants parts per species) (BRPT) by goats and sheep in different seasons.

Replicated	Summer		Autumn		Winter		Overall	
Species	Goat	Sheep	Goat	Sheep	Goat	Sheep	Goat	Sheep
Broom	0.05	2.45	0.85	0.65	0.00	0.00	0.30(7)	1.03(6)
Gorse	10.50	1.17	2.67	0.33	3.33	0.00	5.50(6)	0.50(7)
Manuka	0.00	0.00	0.00	0.00	0.00	0.00	0.00(0)	0.00(0)
Pampas	0.00	0.00	0.00	0.00	0.00	0.00	0.00(0)	0.00(0)
Tagasaste	5.03	0.63	1.20	5.80	20.07	3.27	18.77(5)	3.23(4)
Tauhinu	0.00	0.00	0.00	0.00	0.00	0.00	0.00(0)	0.00(0)
Toe toe	0.00	0.00	0.00	0.00	0.00	0.33	0.00(0)	0.11(8)
Tr medic	23.67	1.33	187.67	8.33	40.33	2.83	83.89(3)	4.17(3)
Unreplicated $								
Ceanothus	7.00	9.50	42.50	1.50	36.50	8.50	28.67(4)	6.50(2)
Bl locust	169.0	543.50	245.5	120.00	2.00	4.00	138.8(2)	222.5(1)
S S gorse	41.00	0.00	252.0	0.00	273.0	6.00	188.67(1)	2.00(5)

Std Err of mean (Season): 22.58; Overall:13.04

$ see table 4.5.

4.4.3.3 *Preference index of shrub species*

Overall preference rankings in relation to relative abundance values of shrub species are presented in Table 4.7, and the details are given in Appendix 4.7 and Appendix 4.8. The ANOVA (GLM) are presented in Appendix 4.9.

A) Relative abundance value (ABUN) and its ratio (ABRAT):

The main effect of animal species (ANID) on relative abundance (ABUN) was not significant, but plant species (SPID) differences were highly significant (P<0.001). There were significant effects of season (SEA) (P<0.05), and site (SITE) (P<0.001) on relative abundance value (ABUN), but the ratio of relative abundance (ABRAT) was not affected by season (SEA) or site (SITE). The first- order interactions between ANID X SPID and ANID X SEA were not significant for ABUN or its ratio (ABRAT). The second order-interactions ANID X SITE X SPID and ANID X SPID X SEA were not significant for either relative abundance (ABUN) or its ratio (ABRAT) (Appendix 4.9).

B) Number of browsing observation (BRW) and its ratio (BRAT):

The main effects of animal species (ANID) and plant species (SPID) on number of browsing observations (BRW) were highly significant (P<0.001) but the browsing observation ratio (BRAT) was not affected by these varibles. The browsing observation ratio (BRAT) was affected by plant species (SPID) (P<0.001), but not by animal species (ANID). The effect due to season (SEA) or site (SITE) was not significant for either browsing observation (BRW) or its ratio (BRAT).

The first- order interactions between ANID X SPID on browsing observation (BRW) and its ratio (BRAT) was highly significant (P<0.001). Similary, there was no effect of season (SEA) on browsing observation (BRW) and its ratio (BRAT). The second order-interactions ANID X SITE X SPID and ANID X SPID X SEA were not significant (Appendix 4.9).

C) Preference Index (INDX):

The main effects of animal species (ANID), site (SITE) and season (SEA) were not significant for preference index (INDX), but the plant species (SPID) effect was highly significant (P<0.001). The first- order interactions between ANID X SPID and ANID X SEA and the second order-interactions ANID X SPID X SEA were not significant (Appendix 4.9).

Overall the most preferred species (defined by the preference rank index) for both goats and sheep was tree medic. In particular, after tree medic goats preferred short spine gorse whereas sheep preferred black locust (Table 4.7).

Table 4.7

Overall ratio of Relative Abundance of shrub species abundance(ABRAT), ratio of browsing observations and the preference Index (INDX) of the shrub species by goats and sheep (in percent ratio).

	Goats			Sheep		
	ABRAT	BRAT	INDX	ABRAT	BRAT	INDX
Broom	0.059	0.048	0.003(6)	0.058	0.093	0.014(4)
Gorse	0.253	0.143	0.001(7)	0.257	0.041	0.001(7)
Manuka	0.089	0.012	0.0005(8)	0.085	0.009	0.0001(10)
Pampas	0.182	0.002	0.0002(11)	0.184	0.000	0.000(0)
Tagasaste	0.076	0.151	0.00682(4)	0.072	0.121	0.007(5)
Tauhinu	0.111	0.002	0.0001(9)	0.107	0.013	0.001(8)
Toetoe	0.176	0.006	0.0001(10)	0.175	0.018	0.0001(9)
Tr Medic	0.001	0.268	0.8376(1)	0.001	0.215	0.790(1)
Ceanothus	0.042	0.092	0.0060(5)	0.044	0.125	0.007(6)
Bl.locust	0.007	0.178	0.0664(3)	0.013	0.398	0.149(2)
SSgorse	0.003	0.249	0.1541(2)	0.002	0.056	0.053(3)
SEmean	0.008	0.031	0.024	0.008	0.031	.024

4.4.4. *Overlap of browsing activities*

The overlap of browsing activities among goats and sheep (overlap coefficient (Cμ) is presented in Table 4.8. Overlap was greater in summer and autumn observation periods than in winter but the seasonal diferences were relatively small.

Table - 4.8

The overlap coefficient of browsing activities (Cμ) by goats and sheep in different harvest seasons (periods are presented in parenthesis).

Season	Mean
Summer (1)	0.713
Summer (6)	0.794
Autumn (2)	0.621
Autumn (3)	0.637
Winter (4)	0.473
Winter (5)	0.575

4.5 *Discussion*

4.5.1 *The Main Animal activities*

Animal activities are divided into alternating periods of feeding, ruminating and rest (Hodgson, 1982a). Feeding can be categorized into either grazing or browsing.

The principal difference in the activities of goats and sheep was that goats spent more time on browsing shrubs than grazing compared to sheep (Table 4.3). The results supported the view that sheep are intermediate grazers and goats are intermediate browsers (Van Soest, 1982; Devendra, 1987).

The browsing activities of goats were similar to the first trial (Chapter-3). However, compared to the first trial idling activities were low, possibly due to the overnight fasting of the animals in this trial. Overnight fasting does not affect diet selection (Hodgson, 1969; Greenwood and Demment, 1988), though animals show a high hunger level compared to non fasting (Kenney and Black, 1984; Jung & Koong, 1985). During the two hour recording period in the present study, idling activities (e.g. standing, lying, ruminating and others) were observed only towards the later part, otherwise the animals were either actively grazing or browsing.

Proportional utilization of browse by goats was high compared to sheep. The utilization coefficient also reinforced the view that goats utilize browse more than sheep (Table 4.4). Russel *et al.*, (1983) also reported that the degree of proportional utilization of grazed indigenous pasture species by goats was greater than that by sheep for all species except *Calluna vulgaris* in indigenous hill vegetation in the West of Scotland.

4.5.2 ***Preference ranking for shrub species***

Preference ranking by animal species is the index of a series of plant species/ morphological units, in terms of the preference exhibited for them (Hodgson, 1979). Also, preference rating depends on the methods of data collection and the statistic used to quantify preference (Nudds, 1980). For instance, the interactions of browsing activity of goats and sheep when analysed using analysis of variance (Table 4.5) were affected by the species that were rarely or never browsed by one or both animal species. Analysis of variance of simple preference (PREF) did not clearly separate the rarely browsed species from the frequently browsed species, yet when proportional utilization was assumed there was a clear cut separation between the rarely and frequently browsed species (Appendix 4.7 and 4.8).

Measurements of relative herbage intakes may also be used as the basis of preference ranking (Hodgson, 1979). When the species were ranked on the basis of intensity of defoliation of the browsed parts (BRPT) the order of ranking of shrub species was similar to the ranking of browsing activities (Table 4.5 and 4.6). However, there were no recorded defoliations for manuka, tauhinu, pampas or toetoe, though there were records of browsing activity on these species. Possibly the animals were testing these shrubs just by taking small amounts of foliage which were difficult to detect while counting the browsed parts. Also, the period of browsing was short so that the degree of defoliation may have been small.

Tagasaste was defoliated equally by goats and sheep (Table 4.5 & 4.6). However, the intensity of defoliation was moderate compared to black locust, short spine gorse, tree medic and ceanothus by both animal species (Table 4.5 & 4.6).

Preference indicates palatability (Johnston, 1988). On this basis palatability of tagasaste was high compared to gorse, broom, manuka, tauhinu, pampas and toe toe. Tree medic was the most palatable species (Table 4.7). Nevertheless, too much palatability is detrimental to plant survival, and its better performance. The regrowth of tree medic was observed to be very slow. One of the reasons for the slow growth of tree medic compared to other shrub species might be due to severe defoliation by both goats and sheep, as there were very few leaves left after each of the grazing periods despite the short period of access.

4.5.3 *Goat and sheep contrasts*

All polyphagous animals exhibit an order of preference for diet when offered a range of potential food plants (Harper, 1977). In the present study these characteristics of preferential browsing on different shrub species were well exhibited. There was a different order of preference for the experimental shrub species by goats and sheep (Table 4.5;4.6; & 4.7). However, the degree of difference was moderate. In housed conditions preferences were also similar between goats and sheep with the same shrubs when offered in a chopped form (Lambert *et al.*, 1989b) (Table 4.9).

Preference depends not only on animal behaviour but also on the presence of potential food items. For example goats were highly selective and utilized a variety of shrub species when there were more shrub species available, as in the present trial. However, in the absence of other shrub species, as for example in the second experiment (Chapter -3), the browsing activity of goats was fully concentrated on tagasaste only. This shows the browsing preference and selective ability of goats. On the other hand it reflected the possibility of tagasaste being a promising forage shrub either as a solo plantation in convential pastures or with other shrub species.

Goats prefer a wide variety of foods including browse and have high tolerance of bitter tastes (Devendra, 1978; Huston, 1978; Devendra and McLeroy, 1982). They have high preference for aromatic herbs (Wilkinson & Stark, 1987). Despite the presence of alkaloids and phenolic compounds in some shrubs such as in manuka (Briggs; Penfold & Short, 1938; Corbett, McDowall, 1958) higher utilizations of this species was an example of such ability of goats over the sheep (Table 4.5).

Sheep may be as selective as goats (Arnold, 1964; 1981; 1987; Eadie, 1970). In this study sheep showed a similar range of preference values to goats (Table 4.5, 4.6, 4.7).

It has been argued that selective feeding on morphological fractions of plants is the important characteristic of goats' feeding behaviour, and the most common plant fractions in the diet of goats have been found to be buds, leaves, fruits and flowers (Hoppe *et al.*, 1977). In the present study the constituents removed were mostly new growth tips and leaves of shrubs. Goats were observed to consume some inflorescences of only ceanothus, though most of the shrub species were bearing flowers throughout the harvest periods (Appendix- 4.2). The reason to avoid the flowering parts of other shrub species such as gorse, tauhinu, manuka, gorse, broom, toetoe and pampas is not known. Avoidance of phenolic compounds may be involved, but no chemical analysis were attempted. However, most of the flower parts except ceanothus were above the eye-level strata of either goats or sheep.

It was assumed that if preferred browse species are available, less preferred species are either rejected or rarely consumed regardless of their abundance (Lacher, Willig and Mares, 1982). Similar behaviour was expressed by sheep and goats in the present study. Browsing activities of sheep were mainly concentrated on black locust and tree medic but, during winter when leaves of black locust started to fall due to its deciduous nature, sheep browsed other species (e.g. ceanothus).

Tree medic was in low abundance but utilization was high compared to pampas, toe toe, tauhinu, and manuka which were high in abundance. Similarly, the unreplicated species short spine gorse, black locust and ceanothus which appeared only once in the experimental unit were still comparatively highly utilized (Table 4.6).

When grazing in common, greater dietary overlap might be possible between goats and sheep due to similar body size (Van Soest, 1982). But, when browse shrubs are available goats tend to be browsers and sheep tend to be grazers as indicated by the present results (Table 4.3). This divergence of feeding strategies might result in an efficient utilization of shrubs and pasture which could increase animal production per unit of grazing land as compared to grazing alone by either species.

Also, the degree of overlap in the diet depends upon the species or forage class available and the seasons grazed by the respective animal species. For instance there was high browsing overlap in summer, that is periods one and six, and a low overlap in winter (periods four and five).

4.5.4 ***Seasonal effects on Preference***

The degree of selection between alternative sward components depends on plant maturity and physical and biochemical characteristics (Hodgson, 1986). In the present experiment there was diversity between the species as well as within the species in morphological, physical and chemical characteristics. Tree medic and short spine gorse were always vegetative throughout the harvest periods.

The intensity of defoliation by goats for gorse was higher in summer than in autumn or winter, and similarly in the case of broom by sheep (Table 4.5). Howe, Barry and Popay, (1988) also reported that gorse was freely consumed by sheep during spring and summer but in winter as the gorse needles became very sharp and hard sheep refused to eat them. The browsing intensity on tagasaste was not affected by season. This may have been due to the vegetative differences among the tagasaste plants, as there were different growth and flowering patterns among them, always some plants were in each growth stage at each season.

The preference for plant species is also influenced by the presence of secondary substances (Provenza & Malacheck 1984; Hodgson, 1986; McCabe and Barry, 1988), which are common in browse species (Barry and Blaney, 1987; McCabe and Barry, 1988). The analysis of these compounds in the experimental shrubs was beyond the objectives of this study. However, the indoor feeding trial of tagasaste by goats did not indicated any ill effects on, or depressed DM intake levels by the goats (Chapter 3).

4.5.5 *Preference ranking in indoor vs outdoor conditions*

Preference between feeds may vary from one situation to another, for example indoor vs field conditions. Lambert *et al.*, (1989b) reported that sheep and goats showed greater preference for hay in indoor conditions compared to the present tested shrub species when they were offered as chopped forage in pair combinations. In contrast to Lambert *et al.*, (1989b) goats spent more time browsing than grazing in the present study (Table 4.3 and Table 3.8: Chapter-3).

Out of the three measure of preference ranking adopted in the present study, probably browsing activity adjusted for rank in abundance produced the best measure of ranking. When the order of the preferred species was compared between indoors (Lambert *et al.*, 1989b) and outdoors (current study) using the same species of plants, there were differences in preference ranking by goats and sheep (Table 4.9). There were some extreme differences in order of preference for some species such as in the case of gorse, ceanothus and black locust (Table 4.9), however, there was close similarity in ranking for the least preferred species such as toetoe and tauhinu. The differences in ranking might be due to differences in methodology and time periods. In the indoor study of Lambert *et al.*, (1989b) the preparation of browse material before feeding in the indoor trial, and the use of hay as a standard for comparison, may also have affected estimates of preference. It is also possible, ofcourse, that the three- year difference in the age of plants between the two situations may have affected palatibility characteristics.

There were some differences between the measures of ranking in field conditions also. When the observations on browsing number was adjusted on the basis of proportional abundance the least abundant species were ranked high (Table 4.9). Similarly, due to the difficulty in detecting the browsed parts for least ranked species the intensity of defoliation (BRPT) could not be estimated, and resulted in 'zero' values (Table 4.6; 4.9).

Table - 4.9

Comparison of relative preference for shrub species by goats and sheep in indoor vs outdoor study order of ranking (mean index values are in parenthesis).

	Indoor Condition		Outdoor conditions					
	1		2		3		4	
	Goats	Sheep	Goats	Sheep	Goats	Sheep	Goat	Sheep
Broom	9 (18)	5 (39)	7 (2.2)	6 (4.2)	7 (0.30)	6 (1.03)	6 (0.00329)	4 (0.01486)
Gorse	1 (71)	1 (65)	6 (4.9)	7 (2.1)	6 (5.50)	7 (0.50)	7 (0.00199)	7 (0.00127)
Manuka	7 (46)	9 (18)	8 (0.4)	10 (0.1)	0 (0.00)	0 (0.00)	8 (0.00055)	10(0.00018)
Pampas	11 (2)	8 (20)	10 (0.2)	0 (0.0)	0 (0.00)	0 (0.00)	11 (0.00002)	0 (0.00000)
Tagasaste	4 (66)	2 (64)	5 (5.8)	4 (6.5)	5 (18.77)	4 (3.23)	4 (0.00682)	5 (0.00746)
Tauhinu	10 (3)	10 (5)	10 (0.1)	9 (0.4)	0 (0.00)	0 (0.00)	9 (0.00008)	8 (0.00123)
Toetoe	8 (23)	7 (21)	9 (0.2)	8 (0.9)	0 (0.00)	8 (0.11)	10 (0.00007)	9 (0.00083)
Tree medic	2 (69)	4 (50)	4 (8.6)	3 (7.2)	3 (83.89)	3 (4.17)	1 (0.83762)	1 (0.79099)
Ceanothus	6 (47)	9 (18)	3 (9.3)	2 (10.3)	4 (28.67)	2 (6.50)	5 (0.00606)	6 (0.00694)
Bl.locust	5 (48)	3 (61)	2 (14.9)	1 (30.3)	2 (138.83)	1 (222.50	3 (0.06641)	2 (0.14996)
S S gorse	3 (68)	6 (37)	1 (25.9)	5 (4.2)	1 (188.67)	5 (2.00)	2 (0.15412)	3 (0.05256)

1=indoor studt; 2,3,4=outdoor study. 1= Lambert *et al.*, (1989b) 2= mean of the browsing activity (PREF), 3= Intensity of browsed parts removed (BRPT), 4= mean of the browsing activity adjusted on abundance.

+=Lambert *et al.*, (1989b) relative intake compared to hay, Means across three season (Spring, Summer and fall),

++ = Present study,

1= Lambert *et al.*, (1989b)

2= mean of the browsing activity (PREF),

3= Intensity of browsed parts removed (BRPT),

4= mean of the browsing activity adjusted on abundance.

4.6 *Conclusions*

Goats spent more time on browsing than grazing compared to sheep. The browsing activity of either goats or sheep was constant throughout the seasons. The proportional utilization of shrubs by goats was higher than sheep.

The patterns of selection exhibited by goats and sheep between the tested shrub species were broadly similar but some differences were noted. For example, short spine gorse ranked higher in preference for goats than for sheep while the reverse was the case for black locust and gorse. The most intensively browsed species were tree medic, black locust, ceanothus, tagasaste, gorse and broom. Seasonal effects were observed for intensity of browsing on gorse by goats and broom by sheep.

When tagasaste was present with other shrub species, as in this study, it was moderately browsed by goats compared to the second experiment (Chapter 3).

A comparision between indoor (Lambert *et al.*, 1989b) and outdoor (present study) studies using the same shrub species showed that there were some specific differences in preference ranking between the two studies, but in general the rankings were similar.

Ranking of shrubs by direct observation of browsing activity in field conditions and subsequent adjustment of the datas for the abundance of individual species offered the best method for defining preference ranking of a range of potential browse species.

Chapter - 5

General conclusions

1.0 An initial indoor feeding trial was carried out to assess the feed value for goats of fresh foliage of tagasaste (*Chamaecytisus palmensis*), feed alone, in comperison with chopped lucerne hay chaff.

1.1 Intake, digestibility and body weight change in goats were similar on tagasaste and on lucerne chaff. There was no indication of aversive constituents limiting intake of tagasaste.

1.2 Tagasaste leaves only were high in *in-vitro* digestibility compared to stems only.. Chemical composition of tagasaste was similar to lucerne hay in N and fibre content but lower in ash.

1.3 Goats consumed most leafy parts of tagasaste which were high in digestibility and N content but low in fibre compared to feed offered.

2.0 In a subsequent small-scale grazing study goats showed a greater preference for browsing on tagasaste compared to grazing on pasture despite the high abundance of pasture mass.

2.1 The change in animal body weight was higher in field conditions compared to housed condition but it is not clear whether this difference reflects the limiting conditions of crate feeding or the value of the mixed diet of grass and browse materials.

3.0 The browsing activities of groups of goats and sheep in plot of mixed browse species were then compared at intervals over a period of twelve months, using an interval-sampling technique.

3.1 Goats spent more time browsing and less grazing compared to sheep. The proportional utilization of shrubs by goats was higher than sheep.

3.2 The patterns of selection exhibited by goats and sheep between the tested shrub species were broadly similar. Most intensively browsed species were tree medic, black locust, ceanothus, tagasaste, gorse and broom. In contrast to sheep, goats preference for short spine gorse was higher; there was a greater preference for black locust and broom by sheep compared to goats.

3.3 In the presence of other shrub species goat prefered tagasaste moderately but, in the abscence of other shrubs, browsing activities of goats were fully concentrated on tagasaste.

3.4 There was a seasonal variations in preference ranking of shrub species by both animal species; for example, preference for gorse was higher in summer than in winter.

3.5 There were some differences in order of preference ranking between indoor (Lambert *et al.*,1989) and outdoor conditions (present study). In indoor condition preference may not be ranked sucessfully. Three different measures were tested to express order of preference index. The ranking of distribution of browsing activity adjusted for varition in browse was considered to provide the best index of preference.

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Appendix

Appendix

Appendix 3.1

Comparative nutritive value of tagasaste (Tag), Leucaena (Leuc), Osier Willo (Oswill), Spring Pasture (past), and lucerne hay (luc hay).

		Tag (1)*	Leuc (2)*	Gorse (3)*	Oswill (4)*	past (5)*	Luc Hay (6)*
Dry-matter	%	27.69	28.03	35.80	32.10	15.30	82.94
OM	%	94.82	89.70	95.98	92.40	-	88.09
GE(Mj/kgDM)		20.12	17.00	21.18	19.69	-	18.30
Nitrogen	%	3.16	2.87	2.02	2.43	3.84	3.21
NDF	%	45.85	-	-	-	-	-
Lignin	%	7.1	9.8	18.47	19.70	2.00	6.75
Cellulose	%	21.48	13.40	26.20	13.40	16.00	22.25
In-vitro							
DMD	%	62.5	62.2	65.3	57.2	71.5	66.32
Sec.comp	-	Nf	Mimo.	ND	Tannin	Rare	Nf

1* = Present study;

2* = Cheva-isarakul & Polikanond, (1985); Sriwattnasombat & Wanput, (1985);

3* = Howe,Barry & Popay,(1988);

4* = McCabe & Barry, (1988);

5* = Clark and Brougham,(1979); Ulyatt et.al.,(1980);

6* = Present study; Sec. comp.=secondary compound;

Mimo=Mimosine,

ND = Not determined;

N = Not found.

Appendix - 4.1

Relative abundance of shrubs

Overall number of plants of individual shrub species (PLN), length of row (LTH), mean height (HIT), mean width (WTH), mean density score (DEN) and the relative abundance value (RAV) (LTH X HIT X WTH X DEN) for shrub species on each nursery site (Appendix 4.1 (Table).

Appendix 4.1 (Table)

	Site - 1						Site - 2					
	PLN	LTH	HIT	WTH	DEN	RAV	PLN	LTH	HIT	WTH	DEN	RAV
Broom	5.7	3.6	1.2	1.1	3.0	22.8	6.5	4.5	1.8	1.2	3.5	34.6
Gorse	6.7	4.6	1.6	1.4	9.7	106.9	7.0	5.0	1.9	1.1	10.0	127.0
Manuka	6.9	5.0	1.4	1.0	5.4	38.8	6.6	5.0	1.4	1.0	5.3	39.4
Pampas	8.6	5.0	1.7	1.2	9.0	96.7	7.3	5.0	1.8	1.0	7.6	68.5
Tagas	5.6	3.6	1.5	1.0	3.2	44.1	2.0	2.1	1.4	0.9	1.8	10.1
Tauh	6.0	4.6	1.1	1.5	5.6	44.7	5.6	5.0	1.2	1.3	6.3	52.5
Toetoe	7.3	5.0	1.6	1.0	9.3	79.7	8.3	5.0	1.7	1.0	9.3	88.2
Tr.med	5.3	2.6	0.4	0.5	1.7	0.9	4.0	1.6	0.4	0.2	1.0	0.1
Ceano	6.0	5.5	1.4	1.5	5.0	58.4	5.5	3.8	0.6	0.6	4.5	11.5
Bl.loc	8.0	2.5	1.5	1.5	2.0	9.7	7.8	5.3	1.2	1.5	4.5	45.3
SS gor	*	*	*	*	*	*	6.6	4.3	1.1	1.3	2.6	16.2
SEmean	0.5	0.2	0.1	0.1	0.2	4.04	0.4	0.2	0.1	0.1	0.2	4.0

*= Missing plants. (LTH, HIT, WTH are in metre).

Appendix - 4.2

Morphology of shrubs

Morphological stage of individual shrub species according to harvest periods.

Broom	Early vegetative + few flowering
Gorse	Early vegetative + few flowering
Manuka	Early vegetative + few flowering
Pampas	Early flowering + some new growth
Tagasaste	Early vegetative
Tauhinu	Early vegetative + few flowering
Toetoe	Early flowering + some new growth
Tree medic	Early vegetative
Ceanothus	Early vegetative + few flowering
Bl.locust	Early vegetative
SS gorse	Early vegetative

Appendix 4.2(continued)

Harvest period - 2

Broom	Early vegetative + few flowers
Gorse	Early vegetative + few flowering
Manuka	Early vegetative + few flowering
Pampas	Early flowering + few in vegetative stage
Tagasaste	Early vegetative
Tauhinu	Early vegetative + few flowering
Toetoe	Early flowering + few in vegetative stage
Tree medic	Early vegetative
Ceanothus	Early vegetative + few flowering
Bl.locust	Early vegetative
S S gorse	Early vegetative

Appendix 4.2(continued)

Harvest period - 3

Broom	Early vegetative + few flowering
Gorse	Full blooming + few vegetative
Manuka	Early vegetative + few flowering
Pampas	Early flowering + few vegetative
Tagasaste	Early vegetative
Tauhinu	Early vegetative + few flowering
Toetoe	Early flowering + few vegetative
Tree medic	Early vegetative
Ceanothus	Early vegetative + few flowering
Bl.locust	Early vegetative
S S gorse	Early vegetative

Appendix 4.2(continued)

Harvest period - 4

Broom	Full vegetative + few flowering
Gorse	Full flowering + few vegetative
Manuka	Full vegetative + few flowering
Pampas	Full flowering + few vegetative
Tagasaste	More than half flowering & few vegetative
Tauhinu	Full vegetative & few flowering
Toetoe	Full flowering + few vegetative
Tree medic	Full vegetative
Ceanothus	Full vegetative + few vegetative
Bl.locust	Full vegetative
S S gorse	Full vegetative

Appendix 4.2(continued)

Harvest period - 5

Broom	Full vegetative & few flowering
Gorse	Full bloom
Manuka	Full vegetative & few flowering
Pampas	Full flowering + few vegetative
Tagasaste	Full blooming & few vegetative
Tauhinu	Full vegetative & few flowering
Toetoe	Full flowering + few vegetative
Tree medic	Full vegetative
Ceanothus	Full vegetative & few flowering
Bl.locust	Full vegetative
S S gorse	Full vegetative

Appendix 4.2(continued)

Harvest period - 6

Broom	Pod bearing + few new growth
Gorse	Early vegetative
Manuka	Full flowering + Few new growth
Pampas	Late vegetative
Tagasate	Pod bearing + New growth started
Tauhinu	Early vegetative
Toetoe	Late vegetative
Tree medic	Early vegetative
Ceanothus	Late vegetative
Bl.locust	Early vegetative
S S gorse	Early vegetative + some are dying

quantitative representation of species (Whittaker, 1975), using the following formula:

$$PS = 1-0.5 \sum |pi - qi| \text{ or } Min |pi, qi|$$

Where:

PS=Percentage Similarity,

pi= Relative proportion of abundance value in site '1',

qi= Relative proportion of abundance value in site '2'.

Appendix 4.3.1

Coefficient of shrub nursery and percentage similarity of two nurseries.

Site- 1		Site - 2	
Species	RAV	Species	RAV
Broom	80.30	Broom	79.12
Gorse	336.25	Gorse	377.00
Manuka	135.83	Manuka	122.33
Pampas	290.33	Pampas	202.50
Tagasaste	152.58	Tagasaste	28.80
Tauhinu	136.03	Tauhinu	153.55
Toetoe	239.25	Toetoe	264.60
Tr. medic	2.67	Tr. medic	0.66
Ceanothus	58.44	Ceanothus	50.88
Bl.locust	20.51	Bl.locust	14.83
S s gorse	*	S s gorse	3.99

The total number of species in site - 1 = 10;

The total number of species in site -2 = 11.

The coefficient of shrub nurseries = 0.95 ,

Percentage of shrub species = 0.87.

*= Missing plant.

Appendix 4.3.2

4.3.2 *Assessment of Resource Use: Utilization of shrub resources.*

Differences in resource exploitation are expressed by interspecific competition among different species of animals (Morse, 1980). In multiple choice food selectivity experiments the term niche breadth is widely used to define range of choice e.g. Levins (1968); Hurlbert (1978); Feinsinger *et al.*, (1981). Niche breadth is defined as a measure of the diversity of resources used by a species population (Giller,1984; Magurren, 1988). It can be measured by an index which indicates the range of the resource states utilized and the relative frequency with which they are utilized (Feinsinger *et al.*, 1981). When a species utilizes all resource items with equal frequency, it will have broad niche.

Several measures of niche breadth that have been proposed by different authors. The most important are:

1) Levins (1968) proposed the reciprocal of the Simpson index as follow -

$$B_n = 1/R \sum_i Pi^2 \qquad \text{(Eq. 1)}$$

Where:

B_n = niche breadth;

R = number of resource states available.

pi = relative proportion of the diet of species i.

2) Hurlbert (1978) proposed the following equation to measure the niche breadth -

$B' = X^2 / A_i \Sigma_i (x^2 /a)$ or $B' = 1/\Sigma_i (P^2 /q)$ ....(Eq. 2)

Where:

x_i =number of i items used by the total population.

$X = \Sigma_i$ xi;

ai = number of items available in resource state i;

$A = \Sigma_i$ ai

OR,

when data is presented as proportions,

pi = xi/X

qi = ai/A,

Σpi = Σqi = 1.0

3) Feinsinger *et al.*, (1981) argued that Czekanowski's index or Proportional Similarity Index is the best available measure to calculate niche breadth .The equation is as follow:

$$PS = 1 - 0.5 \sum_i |pi - qi| \text{ Or } PS = \sum_i \min(pi, qi) \quad \text{(Eq.3)}$$

Where,

pi = proportion of resource items i out of all items used by population.

qi = proportion of i items available in resource state

To find the proper measure to estimate niche breadth for browse shrub resources the above mentioned three different equations were tested on the data set of the first harvest obsewrvation (Chapter -4) of this thesis (Table 4.3.2).

Table -4.3.2

Relative abundance value (ABUN), Ratio 0f the ABUN (ABRAT), Numbers of browsing observations (BRW), and the ratio of BRW (BRAT) for site 1 and 2.

	Site - 1(Goats)				Site - 2 (Sheep)			
Species	ABUN	ABRAT	BRW	BRAT	ABUN	ABRAT	BRW	BRAT
Broom	59.0	0.04628	6.80	0.12048	61.5	0.04488	2.33	0.17949
Gorse	390.0	0.30571	9.52	0.16867	315.3	0.24836	1.00	0.07692
Manuka	117.5	0.09211	1.02	0.01807	113.0	0.08246	0.00	0.00000
Pampas	198.0	0.15521	0.00	0.00000	289.0	0.21089	0.00	0.00000
Tagasaste	26.5	0.02079	6.12	0.10843	120.1	0.08757	0.67	0.05129
Tauhinu	149.4	0.11711	0.00	0.00000	109.5	0.09041	0.00	0.00000
Toetoe	264.6	0.20741	2.04	0.03614	237.0	0.17294	0.33	0.02564
Tr. medic	0.6	0.00045	9.52	0.16867	3.2	0.00234	1.33	0.10256
Ceanothus	49.5	0.03880	3.74	0.06627	57.8	0.04214	0.33	0.02564
Bl.locust	16.2	0.01269	11.90	0.21085	24.8	0.01806	7.00	0.53846
SS gorse	4.4	0.00343	5.78	0.10241	*	*	*	*

Niche Breadth:-

	Site - 1	Site - 2
Levin's Bn(Eq:1)	0.259905	0.230176
Hurlbert's B'(Eq:2)	0.000924248	0.00511108
PS (Eq:3)	0.345342	0.244756

Table 4.3.2 (continued)

Overerlap

Feinsinger *et al.*,1981 (PS): 0.613373

Morisita 1959,modified by Horn (1966); 0.713480 (See 4.3.3).

4.3.3 ***Overlap of browsing activities on forage shrubs***

Comparative studies of diet overlap is important for common grazing management of animal species such as goats and sheep. Overlap can be defined as a shared use of a resource/s by two or more species (Colwell & Futuyma, 1971). For a quantitative analysis of mixed grazing management the degree of overalp between animal species and plant species is necessary.

Dietary overlap between goats and sheep in hill country pastures with different combinations of animal association were reported by Clark *et al.* (1982). No attempts were made to measure dietary overlap in mixed shrub and pastures conditions.

Different methods are used to estimate the degree of diet overlap among different species.

1) Czekanowski's index or Proportional Similarity Index (Feinsinger *et al.*, 1981) is also used to estimate overlap by substracting dietary proportions for the two animal species. The equetion is the same as follow

$PS = 1-0.5 \sum_i |pi-qi|$ Or $PS = \sum_i \min(pi, qi|$ .... (Eq. 1)

Where,

pi = proportion of browsing observations by goats for species 'i'.

qi = proportion of browsing observations by sheep for the same species of shrub.

By using Feinssinger *et al.*, (1981) Proportional Similarity Index the overlap coefficient are presented in Table 4.3.2.

2) Morisita 1959; as modified by Horn (1966), suggested the following formula to measure the overlap coefficient ($C\mu$). This formula is found suitable to measure the browsing activity of animals, as the data can be expressed as the proportion of activity of animal species for shrub species 'i'. Alternarively, if we are interested in the overlap in intensity of defoliations of browsed parts from shrub species 'i' the data could be expressed as the proportions of the total browsed parts from various shrub species by animal species such as goats and sheep. And, also the overlap coefficient varies from 0 to 1 (completely distinct to identical food samples), which also gives an empirical advantage. The equation is as follow -

$$C\mu = \frac{2 \sum_{i=1} XiYi}{\sum_{i=1} Xi^2 + \sum_{i=1} Yi^2} \qquad \text{.......(Eq. 2).}$$

Where:

= total no.of plant griups,

Xi;Yi= proportion of the total diet used by species X and Y.

Using the Morosita (1959); as modified by Horn (1966) equation to calculate the overlap coefficient on the data set of 4.3.2 the overlap coefficient was found to be 0.7135.

Appendix 4.4

Measurements of forage preferences: Relative Preference Index

This index defines the differential dietary preferences for forage species expressed by different animal species. The degree of competition is determined by the amount of consumption of different species by animals and their preference for forage plants (Smith, 1953).

There are several numerical methods or indices reported for determining preference, which are presented as follows:-

1) Ivelev (1961) proposed an 'electivity' index to measure preference by the following equation :-

$$Ri = (Fi - Hi)/(Fi + Hi) \quad \text{(Eq. 1)}$$

Where:

Ri = Electivity index,

Fi = amount of forage of species i in diet;

Hi = amount of herbage of species i in offer,

2) Van Dyne and Heady (1965) proposed the simple ratio of food available and food consumed for specific food items as follows :-

$$SR = (Fi + 0.01)/(Hi + 0.01) \quad \text{(Eq. 2)}$$

Where:

SR = Simple ratio ,

Fi = amount of forage of species i in diet;

Hi = amount of herbage of species i in offer,

3) The natural logarithm of (SR) in equation 2 may also be used for preference calculation (Skiles, 1984):

$$R = \ln (SR) \quad \text{(Eq. 3)}$$

Where:

R = Logarithm of simple ratio,

SR = Relative preference Index in simple ratio.

4) Skiles (1984) modified the Ivelev's (1961) equation for electivity index as followed:-

$$R = (Ri + 1) / \sum i \ (Ri) + n \qquad \text{(Eq. 4)}$$

Where:

R =Preference Index;

Ri = Ivelev's Electivity Index;

n = Total number of species

5) The Relative preference index or selection ratio is widely used to calculate preference for food items e.g. Hodgson (1979); Hodgson and Grant (1981); Jung; Bennett and Sahlu (1989). The equation is as follow:

$$RPI = Di/Ri \qquad \text{(Eq. 5)}$$

Where:

RPI = Selection Ratio or Relative preference index.

Di = weight of the forage species i in diet (percent)

Ri = weight of the forage species i in range Composition

6) Most of these equations give similar orders of preference though ranges of value and neutrality values may differ between them (Table -4.4). Also, the above indices may include available species which are never consumed by animals. To avoid such problems of preference ranking, I examined a modified form of relative preference index or Selection Ratio.

Bp =(Ni/Ai)/(Σ NjAj) ....(Eq. 6).

Where;

Bp = Browsing preference index;

Ni = Number of observations on browsing activities for species 'i',

Ai = Abundance of browse for the same species.

NjAj = Products of (Ni/Ai)

This equation results in a statistic with normal distribution in the range 0 to 1 (completely ignored to completely utilized) and neutrality 0.5.

The above equetions were tested on the data set of Table 4.3.1 and the values of the alternative indices are presented in the following Table: 4.4

Table -4.4

Preference indices value of different equations (Rank order in parenthesis).

A) Goats:

Index*

Index	1	2	3	4	5	6
Broom	0.44(5)	2.31(5)	0.84(5)	0.094(5)	2.60(5)	0.0059(5)
Gorse	-0.28(7)	0.56(7)	-0.56(7)	0.08(7)	0.55(7)	0.001(7)
Manuka	-0.67(8)	0.27(8)	-1.29(8)	0.08(8)	0.19(8)	0.0001(8)
Pampas	-1.00(10)	0.06(11)	-2.80(11)	0.08(10)	0.00(0)	0.000(0)
Tagasaste	0.67(4)	3.84(4)	1.34(4)	0.09(4)	5.21(4)	0.012(4)
Tauhinu	-1.00(10)	0.07(10)	-2.54(10)	0.08(10)	0.00(0)	0.000(0)
Toetoe	-0.70(9)	0.21(9)	-1.55(9)	0.08(9)	0.17(9)	0.0004(9)
Tr. medic	0.99(1)	17.10(1)	2.83(1)	0.09(1)	377.3(1)	0.8689(1)
Ceanothus	0.26(6)	1.56(6)	0.44(6)	0.09(6)	1.70(6)	0.0039(6)
Bl.locust	0.88(3)	9.72(2)	2.27(2)	0.09(3)	16.60(3)	0.0382(3)
SS gorse	0.93(2)	8.37(3)	2.12(3)	0.09(2)	29.86(2)	0.0687(2)

*= See Table 4.4 B

Table 4.4 (continued)

B) Sheep:

Index*

Index	1	2	3	4	5	6
Broom	0.59(3)	3.45(3)	1.23(3)	0.10(3)	3.99(3)	0.050(3)
Gorse	-0.52(6)	0.33(6)	-1.08(6)	0.09(6)	0.30(6)	0.003(6)
Manuka	-1.00(8)	0.10(8)	-2.22(8)	0.09(8)	0.00(0)	0.000(0)
Pampas	-1.00(8)	0.04(10)	-3.09(10)	0.09(8)	0.00(0)	0.000(0)
Tagasaste	-0.26(5)	0.62(5)	-0.46(5)	0.09(5)	0.58(5)	0.007(5)
Tauhinu	-1.00(8)	0.09(9)	-2.30(9)	0.09(8)	0.00(0)	0.000(0)
Toetoe	-0.74(7)	0.19(7)	-1.63(7)	0.09(7)	0.14(7)	0.002(7)
Tr. medic	0.95(1)	9.12(2)	2.21(2)	0.11(1)	43.92(1)	0.553(1)
Ceanothus	-0.24(4)	0.68(4)	-0.38(4)	0.09(4)	0.60(4)	0.007(4)
Bl.locust	0.93(2)	19.54(1)	2.97(1)	0.11(2)	29.81(2)	0.376)
SS gorse	*	*	*	*	*	*

Index*1= Electivity Index (Ivlev, 1961), 2= Simple Ratio (Van Dyne and Heady, 1965), 3= The Natural Logirithm of Simple Ratio (Skiles, 1984), 4= Modified Ivelev's (1961) Elec Skiles (1984), 5= The Relative Preference Index or Selection Ratio by Hodgson, (1979); Hodgso and Grant, (1981); Loehle and Rittenhouse, (1982); Jung, Bennett and Sahlu,(1989).

6) Browsing preference Index (Current modified). * = missing plant species.

In equation 1 the electivity Index (Ivelev, 1961) ranges from -1 to +1, the negative value indicating the degree of rejection. In equation 2 (Van Dyne and Heady, 1965) the addition of 0.01 to all proportionate values gave some correction for available species which were not utilized. In equation 3 natural logarithms of vegetation and dietary proportions (Skiles, 1984) yielded simply the natural logarithm of selection ratio (SR). Equation 4 gives index values ranging from 0 to 1 but is also subject to distention by data from species which are not utilized. The fifth equation gives the clearest expression of preference index, but the range of value is from 0 to infinity.

To control such shew the modification of RPI in equation 6 gives the best result; the index value ranges from 0 to 1 with normal distribution and also clear indication of acceptance or rejection by browsing animals.

Appendex - 4.5

Effects of seasons on animal activities, Browsing, grazing

and idling activities of goats and sheep according to mean season.

	Summer		Autumn		Winter	
	Goats	Sheep	Goats	Sheep	Goats	Sheep
Browsing	42.54	13.05	48.09	10.46	43.39	11.16
Grazing	49.05	79.72	44.95	79.73	51.72	82.03
Idling	8.41	7.23	6.97	9.81	4.89	6.81
SE mean	2.34	2.33	2.17	2.17	2.23	2.24

Appendix 4.6

ANOVA (GLM) of Browsing activity (PREF) and Intensity of defoliation (BRPT) by goats and sheep.

Source		PREF			BRPT		
	DF	SS	F value	PR>F	SS	Fvalue	PR>F
REP	2	0.0214	5.2	0.0065	9004.1	1.5	0.2321
SPID	10	0.8209	39.7	0.0000	443656.5	14.5	0.0001
ANID	1	0.0000	0.0	1.0000	11909.4	3.9	0.0499
SEA	2	0.0000	0.0	1.0000	13462.3	2.2	0.1136
SPID*ANID	10	0.1543	7.5	0.0001	121533.4	3.9	0.0001
SPID*SEA	20	0.2683	6.5	0.0001	285270.4	4.6	0.0001
ANID*SEA	2	0.0000	0.0	1.0000	25685.3	4.2	0.0164
SPID*ANID*SEA	20	0.0820	1.9	0.0096	171549.0	2.8	0.0001
REP*SPID	15	0.0209	0.6	0.8080	50503.6	1.1	0.3582
REP*SEA	4	0.0054	0.6	0.6232	8397.4	0.6	0.6022
REP*SPID*SEA	30	0.0532	0.8	0.6795	53627.8	0.5	0.9588

REP= Replication; SPID=Shrub species; ANID=Animal species; SEA= Season (Summer: Feb, Nov; Autumn: Mar,Apr and Winter: May and June.

Preference ranking of shrub species by goats and sheep, Relative Abundance (ABUN) and ratio of abundance (ABRAT), number browsing observation (BR' and ratio of browsing observation (BRAT), browsing preference index (INDX) in different harvest periods. Summary of the Index is presented in Appendix 4.8; for ANOVA, see Appendix 4.9).

Period -1

	Goats (Site -2)					Sheep (Site -1)				
	ABUN	ABRAT	BRW	BRAT	INDX	ABUN	ABRAT	BRW	BRAT	INDX
Broom	59.0	0.040	6.8	0.121	0.0059	61.5	0.045	2.3	0.179	0.0504
Gorse	390.0	0.306	9.5	0.169	0.0013	315.3	0.248	1.0	0.077	0.0039
Manuka	117.5	0.092	1.0	0.018	0.0005	113.0	0.083	0.0	0.000	0.0
Pampas	198.0	0.155	0.0	0.000	0.0	289.0	0.211	0.0	0.000	0.0
Tagasaste	26.5	0.021	6.1	0.108	0.0120	120.1	0.087	0.7	0.051	0.0074
Tauhinu	149.4	0.117	0.0	0.000	0.0	109.5	0.090	0.0	0.000	0.0
Toetoe	264.6	0.207	2.0	0.036	0.0004	237.0	0.173	0.3	0.026	0.0019
Tree medic	0.6	0.001	9.5	0.169	0.8689	3.2	0.002	1.3	0.103	0.5533
Ceanothus	49.5	0.039	3.7	0.066	0.0039	57.8	0.042	0.3	0.026	0.0077
Black locust	16.2	0.013	11.9	0.211	0.0382	24.8	0.018	7.0	0.538	0.3756
S s gorse	4.4	0.003	5.8	0.102	0.0688	*	*	*	*	*

Appendix 4.7 Continued..

Period -2

	Sheep(site-2)					Goats(site-1)				
	ABUN	ABRAT	BRW	BRAT	INDX	ABUN	ABRAT	BRW	BRAT	INDX
Broom	78.7	0.0517	0.3	0.0278	0.0009	78.0	0.0505	4.6	0.0899	0.0089
Gorse	370.5	0.3024	0.0	0.0000	0.0000	334.2	0.2379	10.4	0.2011	0.0042
Manuka	117.0	0.0907	0.7	0.0556	0.0011	134.0	0.0839	1.9	0.0370	0.0022
Pampas	198.0	0.1535	0.0	0.0000	0.0000	289.0	0.2181	0.0	0.000	0.0000
Tagasaste	26.5	0.0257	1.6	0.1389	0.0097	150.1	0.1049	7.1	0.1376	0.0066
Tauhinu	149.4	0.1159	0.0	0.0000	0.0000	132.8	0.0878	0.3	0.0053	0.0003
Toe toe	264.6	0.2052	0.0	0.0000	0.0000	237.0	0.1657	0.0	0.0000	0.0000
Tree medic	0.6	0.0004	2.6	0.2222	0.9034	2.8	0.0019	18.3	0.3545	0.9057
Ceanothus	49.5	0.0384	0.7	0.0556	0.0026	57.8	0.0404	3.3	0.0635	0.0079
Bl.locust	8.1	0.0126	5.6	0.4722	0.0675	12.4	0.0087	5.7	0.1111	0.0642
Ss gorse	4.4	0.0034	0.3	0.0278	0.0147	*	*	*	*	*

Appendix 4.7 Continued.......

Period -3

	Goats(site-2)					Sheep(site-1)				
	ABUN	ABRAT	BRW	BRAT	INDX	ABUN	ABRAT	BRW	BRAT	INDX
Broom	78.7	0.0689	0.0	0.0000	0.0000	78.0	0.048	1.9	0.1892	0.0334
Gorse	370.5	0.2732	1.9	0.0429	0.0002	334.2	0.234	0.3	0.0270	0.0009
Manuka	117.0	0.0925	0.0	0.0000	0.0000	134.0	0.085	0.0	0.0000	0.0000
Pampas	198.0	0.1702	0.5	0.0123	0.0001	289.0	0.210	0.0	0.0000	0.0000
Tagasaste	26.5	0.0369	3.3	0.0736	0.0028	150.1	0.111	2.2	0.2162	0.0167
Tauhinu	149.4	0.1221	0.0	0.0000	0.0000	132.8	0.094	0.8	0.0811	0.0074
Toe toe	264.6	0.1854	0.0	0.0000	0.0000	237.0	0.159	0.5	0.0541	0.0029
Tree medic	1.1	0.0004	10.1	0.2269	0.8105	2.8	0.002	1.1	0.1081	0.6270
Ceanothus	49.5	0.0416	5.5	0.1227	0.0042	57.8	0.047	0.3	0.0270	0.0049
Bl.locust	16.2	0.0057	12.6	0.2822	0.0708	12.4	0.008	3.0	0.2973	0.3066
Ss gorse	4.4	0.0031	10.7	0.2393	0.1112	*	*	*	*	*

Appendix 4.7 Continued.......

Period -4

	Goats(site-2)					Sheep(site-1)				
	ABUN	ABRAT	BRW	BRAT	INDX	ABUN	ABRAT	BRW	BRAT	INDX
Broom	78.7	0.0800	0.3	0.0056	0.0001	78.0	0.0525	0.3	0.0286	0.0023
Gorse	370.5	0.2643	3.9	0.0782	0.0006	334.2	0.2265	1.4	0.1429	0.0027
Manuka	117.0	0.0895	0.0	0.0000	0.0000	134.0	0.0821	0.0	0.0000	0.0000
Pampas	198.0	0.1647	0.0	0.0000	0.0000	289.0	0.2033	0.0	0.0000	0.0000
Tagasaste	26.5	0.0472	10.8	0.2179	0.0095	150.1	0.1174	1.4	0.1429	0.0052
Tauhinu	149.4	0.1181	0.0	0.0000	0.0000	132.8	0.1016	0.0	0.0000	0.0000
Toe toe	264.6	0.1871	0.0	0.0000	0.0000	237.0	0.1544	0.0	0.0000	0.0000
Tree medic	0.6	0.0004	5.8	0.1173	0.6842	2.8	0.0014	2.8	0.2857	0.8543
Ceanothus	49.5	0.0403	6.4	0.1285	0.0066	57.8	0.0527	1.7	0.1714	0.0139
Bl.locust	8.1	0.0055	2.2	0.0447	0.0167	12.4	0.0081	2.3	0.2286	0.1215
Ss gorse	4.4	0.0029	20.3	0.4078	0.2823	*	*	*	*	*

Appendix 4.7 Continued.......

Period -5

	Sheep(site-2)					Goats(site-1)				
	ABUN	ABRAT	BRW	BRAT	INDX	ABUN	ABRAT	BRW	BRAT	INDX
Broom	78.7	0.0857	0.8197	0.0909	0.0013	78.0	0.0521	0.6	0.0161	0.0008
Gorse	370.5	0.2657	0.0000	0.0000	0.0000	339.6	0.2194	6.3	0.1694	0.0019
Manuka	117.0	0.0899	0.0000	0.0000	0.0000	134.0	0.0948	0.3	0.0081	0.0002
Pampas	198.0	0.1655	0.0000	0.0000	0.0000	289.0	0.2011	0.0	0.0000	0.0000
Tagasaste	26.5	0.0552	0.2732	0.0303	0.0007	150.1	0.1258	5.9	0.1613	0.0032
Tauhinu	149.4	0.1089	0.0000	0.0000	0.0000	132.8	0.1005	0.3	0.0081	0.0002
Toe toe	264.6	0.1803	0.2732	0.0303	0.0002	237.0	0.1528	0.0	0.0000	0.0000
Tree medic	0.6	0.0004	2.4590	0.2727	0.8614	2.8	0.0014	20.5	0.5565	0.9897
Ceanothus	49.5	0.0472	4.0984	0.4545	0.0118	57.8	0.0521	2.9	0.0806	0.0039
Bl.locust #	0	0	0	0	0	*	*	*	*	*
S s gorse	4.4	0.0012	1.0929	0.1212	0.1246	*	*	*	*	*

Appendix 4.7 Continued.......

Period -6

	Goats(site-2)					Sheep(site-1)				
	ABUN	ABRAT	BRW	BRAT	INDX	ABUN	ABRAT	BRW	BRAT	INDX
Broom	108.30	0.0590	1.7857	0.0566	0.0039	100.8	0.0685	0.5952	0.0435	0.0008
Gorse	360.00	0.2202	6.2500	0.1981	0.0037	390.0	0.2699	0.0000	0.0000	0.0000
Manuka	166.00	0.0854	0.2976	0.0094	0.0005	148.5	0.0849	0.0000	0.0000	0.0000
Pampas	297.00	0.1879	0.0000	0.0000	0.0000	225.0	0.1650	0.0000	0.0000	0.0000
Tagasaste	195.00	0.1234	6.5476	0.2075	0.0069	40.2	0.0364	2.0833	0.1522	0.0050
Tauhinu	175.32	0.1210	0.0000	0.0000	0.0000	174.3	0.1353	0.0000	0.0000	0.0000
Toe toe	250.50	0.1582	0.0000	0.0000	0.0000	264.6	0.1797	0.0000	0.0000	0.0000
Tree medic	1.60	0.0010	5.9524	0.1887	0.7667	0.6	0.0004	4.1667	0.3044	0.9466
Ceanothus	61.88	0.0391	2.9762	0.0943	0.0099	57.8	0.0392	0.2976	0.0217	0.0007
Bl.locust	42.08	0.0048	7.7381	0.2453	0.2084	28.4	0.0193	6.2500	0.4565	0.0285
Ss gorse	*	*	*	*	*	2.1	0.0014	0.2976	0.0217	0.0183

*= missing plant species

=No foliage to browse.

Appendix 4.8

Browsing preference index for shrub species by goats and sheep in different harvest period (Browsing preference Index :Summary data).

GOATS Seasons

	Sum	Aut	Aut	Win	Win	Sum	Overall	SE mean
Broom	0.0059	0.0089	0.0000	0.0001	0.0008	0.0039	0.0033	0.0025
Gorse	0.0013	0.0042	0.0002	0.0006	0.0019	0.0037	0.0020	0.0017
Manuka	0.0005	0.0022	0.0000	0.0000	0.0002	0.0005	0.0005	0.0003
Pampas	0.0	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0001
Tagasaste	0.0120	0.0066	0.0028	0.0095	0.0032	0.0069	0.0068	0.0025
Tauhinu	0.0	0.0003	0.0000	0.0000	0.0002	0.0000	0.0001	0.0001
Toe Toe	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0001
Tree medic	0.8689	0.9057	0.8105	0.6842	0.9897	0.7667	0.8376	0.0440
Ceanothus	0.0039	0.0079	0.0042	0.0066	0.0039	0.0099	0.0061	0.0010
Black loc	0.0382	0.0642	0.0708	0.0167	*	0.2084	0.0664	0.0315
SS gorse	0.0688	*	0.1112	0.2823	*	*	0.1541	0.0653

* = Not available.

Appendix 4.8 (continued)

B SHEEP Seasons

	Sum	Aut	Aut	Win	Win	Sum	Overall	SE mean
Broom	0.0504	0.0009	0.0334	0.0023	0.0013	0.0008	0.0149	0.0088
Gorse	0.0039	0.0000	0.0009	0.0027	0.0000	0.0000	0.0013	0.0088
Manuka	0.0	0.0011	0.0000	0.0000	0.0000	0.0000	0.0002	0.0002
Pampas	0.0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Tagasaste	0.0074	0.0097	0.0167	0.0052	0.0007	0.0050	0.0075	0.0022
Tauhinu	0.0	0.0000	0.0074	0.0000	0.0000	0.0000	0.0012	0.0012
Toe Toe	0.0019	0.0000	0.0029	0.0000	0.0002	0.0000	0.0008	0.0005
Tree medic	0.5533	0.9034	0.6270	0.8543	0.8614	0.9466	0.7910	0.0656
Ceanothus	0.0077	0.0026	0.0049	0.0139	0.0118	0.0007	0.0069	0.0021
Bl.locust	0.3756	0.0675	0.3066	0.1215	*	0.0285	0.1500	0.0633
SS gorse	*	0.0147	*	*	0.1246	0.0183	0.0526	0.0360

*=Not available.

Appendix 4.9

Analysis of varience of abundance ABUN and ABRAT in 4.9.1; browsing observation BRW and BRAT in 4.9.2, and preference index are presented in 4.9.3.

(Data set of this anlysis are presented in Appendix 4.7.)

4.9.1 Relative abundance value (ABUN) and its ratio (ABRAT):

		ABUN			ABRAT		
SOURCE	DF	SS	Fval	PR>F	SS	Fval	PR>F
ANID	1	277.6	1.6	0.2054	0.0002	0.0	0.9893
SPID	10	1475629.0	882.1	0.0	0.76	689.6	0.0000
SEA	2	1320.9	3.9	0.0277	0.0001	0.04	0.9622
SITE	1	7555.8	45.2	0.0001	0.0001	0.01	0.9097
ANID*SITE	1	2003.5	11.9	0.0013	0.0002	0.02	0.8817
SITE*SPID	9	70182.4	46.6	0.0001	0.0343	34.45	0.0001
ANID*SPID	10	538.8	0.3	0.9702	0.0003	0.29	0.9789
ANID*SEA	2	415.3	1.2	0.3004	0.0000	0.01	0.9937
ANID*SITE*SPID	9	974.4	0.6	0.7497	0.0005	0.54	0.8374
ANID*SPID*SEA	40	1590.2	0.2	1.0000	0.0039	0.89	0.6406

4.9.2 Number of browsing observation (BRW) and its ratio (BRAT):

		BRW			BRAT		
SOURCE	DF	SS	Fvalue	PR>F	SS	Fvalue	PR>F
ANID	1	326.1	68.41	0.001	0.000	0.00	0.9902
SPID	10	788.2	16.54	0.001	1.063	24.13	0.0001
SEA	2	0.2	0.02	0.980	0.007	0.78	0.4651
SITE	1	0.3	0.07	0.791	0.005	1.06	0.3094
ANID*SITE	1	0.9	0.19	0.661	0.006	1.42	0.2406
SITE*SPID	9	56.5	1.32	0.260	0.054	1.37	0.2365
ANID*SPID	10	378.5	7.94	0.001	0.246	5.59	0.0001
ANID*SEA	2	2.0	0.21	0.811	0.001	0.15	0.8570
ANID*SITE*SPID	9	59.8	1.39	0.225	0.069	1.75	0.1110
ANID*SPID*SEA	40	282.8	1.48	0.112	0.294	1.67	0.0580

4.9.3 Index (INDX):

		INDX		
SOURCE	DF	SS	Fvalue	PR>F
ANID	1	0.002	0.10	0.7568
SPID	10	7.032	289.53	0.0001
SEA	2	0.001	0.12	0.8902
SITE	1	0.002	0.94	0.3379
ANID*SITE	1	0.002	0.70	0.4093
SITE*SPID	9	0.081	3.69	0.0021
ANID*SPID	10	0.035	1.46	0.1943
ANID*SEA	2	0.001	0.03	0.9736
ANID*SITE*SPID	9	0.100	4.59	0.0004
ANID*SPID*SEA	40	0.085	0.88	0.6586