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Original article

Plant and vegetation preferences for a high and a moderate yielding Norwegian dairy cattle breed grazing semi-natural mountain pastures

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Abstract – Plant and vegetation preferences of two Norwegian cattle breeds grazing semi-natural mountain pastures were studied for two weeks at two farms during one summer. Two rather different grazing sites gave the opportunity to study the two breeds at different pasture qualities, as well as to test if there is any interaction between breeds and study sites. Each of the two herds consisted of the old, moderate yielding Norwegian dairy breed Blacksided Trønder and Nordland Cattle (STN) and the modern, high yielding dairy breed Norwegian Red (NRF). In order to measure the plant preferences of the animals, faeces samples were collected and analysed for plant fragments. In addition, GPS-data showed the terrain chosen by the herds, and vegetation maps were drawn to find the connections between the grazed vegetation and plant preferences. The study shows that on nutrient and especially species rich vegetation growing on base and nutrient rich soil, as at the first study site (Skåbu), the plant species, plant genera and plant groups analysed for in the faeces samples indicate that both the STN and NRF breeds graze very much the same vegetation. However, the results from the second study site (Valdres), where the soil is less fertile, the plant species diversity is lower and the plant species distribution less uniform, the moderate yielding NRF breed seems to cover its higher nutritious requirements by grazing in areas with more nutrient rich vegetation compared to the lower yielding breed, STN.

grazing preferences / cattle / intensive and extensive breeds / pasture management / semi-natural grasslands

Résumé – Préférences en termes de couvert végétal et d'espèces végétales des races bovines norvégiennes à forte production laitière ou modérée pâturant des prairies d'altitude semi-naturelles. Les préférences alimentaires de deux races bovines norvégiennes pâturant des prairies

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d'altitude semi-naturelles ont été étudiées durant deux semaines dans deux fermes pendant un été. Deux sites de pâturage ont permis d'étudier les deux races face à différentes qualités de pâturage et de tester une éventuelle interaction entre les races et les sites d'étude. Chacun des deux troupeaux comprenait des bovins laitiers de race Blacksided Trønder et Nordland (STN, race norvégienne ancienne avec une production laitière modérée) et des bovins de race Pie rouge (NRF, race prédominante en Norvège avec une production laitière élevée). Pour mesurer les préférences alimentaires des animaux au pâturage, des échantillons de fèces ont été collectés et analysés. En outre, les données GPS ont permis de localiser le site privilégié de pâture des animaux et la cartographie de la végétation a eu pour but de déterminer les relations existantes entre la végétation pâturée et la préférence des animaux pour certaines espèces végétales. Sur un couvert végétal riche en éléments nutritifs et particulièrement riche en espèces végétales se développant sur un sol basique et riche en nutriments, comme sur le premier site d'étude (Skåbu), les espèces, les genres et les familles de plantes détectées dans les échantillons de fèces indiquent que les races STN et NRF pâturent la même végétation. Sur le second site (Valdres), où le sol est moins fertile, la diversité des espèces est inférieure et la distribution des espèces est moins uniforme, la race NRF semble couvrir ses besoins nutritifs plus élevés en pâturant les secteurs où la végétation est nutritivement la plus riche comparativement à la race STN.

préférence au pâturage / bovin / élevage extensif et intensif / gestion du pâturage / prairies semi-naturelles

1. INTRODUCTION

Semi-natural grasslands are closely linked to transhumance (summer mountain farming) [23, 28]. This livestock production system is characterised by continuity over centuries of traditional and extensive use, without cultivation of the grazing areas. The system creates some extremely species-rich, semi-natural grasslands. Due to transition to modern livestock production systems in Norway, with a strong decline in the utilisation of outlying land, the area of semi-natural grasslands has been reduced considerably during the last 50 years. This has led to extensive landscape changes [7, 29]. Large herbs have invaded abandoned grasslands, succeeded by shrubs and at last forests, and many of the semi-natural vegetation types characterising the grasslands have thus become highly threatened [3, 8, 10, 11, 13, 19]. In Norway about 30% of the red list (threatened) species are declining due to the reduction of semi-natural vegetation types, especially old grasslands [9]. The former widespread, open grasslands now mostly remain as fragments, which still may be very species-rich [37]. Their continued existence and conservation value depend upon continued traditional use or special management measures. When managing these semi-natural grasslands, it is especially important to graze the entire area, since it consists of small-scale patches of different vegetation types within a single field. To maintain the biodiversity of semi-natural grasslands it is therefore necessary to develop management methods taking this into account [28].

A survey conducted by Sæther and Vangen [40] revealed that farmers utilising the low yielding Norwegian dairy breed Blacksided Trønder and Nordland Cattle (STN) expected this breed to utilise extensive grasslands better than cows of the moderate yielding Norwegian Red (NRF) breed, without any further explanation of the expression "better". The results from a study by Auestad et al. (personal communication) comparing the grazing behaviour of NRF and the old native cattle breeds STN and Westland Fjord Cattle indicated that the old breeds spend more time grazing in undulating terrain than the modern breed (NRF).

Few studies have been performed to compare breeds with different production

levels with regards to their plant and vegetation preferences in semi-natural grasslands. The review article by Rook and Tallowin [34] even claims that there is only anecdotal evidence for breed differences in dietary choice of grazing animals, but little experimental evidence, with genetic effects often confounded with background experience.

A simplified explanation of the resource allocation theory, launched by Beilhartz [4], implies that if the total available resources for an animal are constant, animals that are selected for higher production need to allocate more of their available resources to the increased production, at the expense of resources otherwise spent on less important fitness traits. The need to allocate the resources might only be compensated for by environmental factors to a certain extent. Several studies [1, 6, 21, 30, 31, 36] have shown that breeds and/or lines selected for high production intensity generally show lower levels of activity than breeds and lines not selected for the same high production intensity.

Differences in the level of activity linked to differences in genetic merits are the basis of the contra free loading phenomenon, described by Inglis et al. [20], Lindqvist et al. [25] and Schuts et al. [36]. The contra free loading phenomenon is defined as the animals' choice of difficult over easily accessible fodder. Lindqvist et al. [25] conclude that this difference might represent a genetically based difference in foraging strategy, since the low merit animals tend to choose the difficultly accessible fodder at a higher rate than the high merit animals. The referred studies were done on mice and poultry, and are relevant when studying differences in foraging strategy between two cattle breeds with different yielding levels, since they deal with relatively general behaviour patterns in animals.

On the basis of these theories and studies, this study addresses the following question: when grazing on extensive pastures (semi-natural mountain grasslands) where nutrient rich grazing plants are more spread over the area than on traditional cultivated grasslands, genetic high yielding cows will spend less energy walking around (= have lower level of activity) but focus more on finding the plant species and vegetation types that satisfy their hunger most efficiently than the genetic lower yielding cows.

2. MATERIALS AND METHODS

2.1. Breeds and herds

The two breeds in this study were Norwegian Red (NRF) and Blacksided Trønder and Nordland Cattle (STN). The NRF breed is by far the most common dairy breed in Norway, since approximately 97% of all dairy cattle belong to this breed. The STN breed has the biggest population size of the six old native cattle breeds still found in Norway; although it only has 0.17% of the population size of NRF. Average milk yields of STN cows are 65.6% of the yield average of NRF cows.

The NRF breed has been efficiently selected for higher milk production through a modern breeding programme since the breed's establishment in 1939. Since the 1970s the breeding goal has broadened and now includes milk production, growth, health and fertility traits. Due to its small population size, STN has had a more extensive breeding programme with a focus on breed type, increased milk production and avoidance of inbreeding.

When selecting herds for this study, many demands were to be fulfilled; the farms should have well established herds, in which the animals were familiar with each other and the grazing areas, should practise summer farming on semi-natural

Table I. Milk production and herd size in 2002 for the two studied farms, and the corresponding national means.

	National figures			Valdres		Skåbu	
	Total dairy population	STN	NRF	STN	NRF	STN	NRF
Population size	286 000	475	277 000	5	4	6	3
kg milk per cow	6 190	4 060	6 190	4 444	5 628	4 538	6 036
Fat %	4.2	4.2	4.2	4.4	4.2	3.9	3.9
Protein %	3.2	3.3	3.2	3.4	3.3	3.4	3.1

References: Statistics Norway [39] and TINE [42].
STN: Blacksided Trønder and Nordland Cattle.
NRF: Norwegian Red Cattle.

grasslands, should have both NRF and STN cows and there should be at least 10 cows in each herd. Furthermore, it was of interest to have cows of about the same relative similar age and lactation stage.

Two farms practising traditional summer farming based on semi-natural grasslands in mountain areas were chosen for the study. The two summer farms were Skogstadstølen in Valdres and Brenden in Skåbu, both situated in the county of Oppland in central Norway. The herds consisted of both purebred STN and purebred NRF cows, approximately 50% of each breed, and some crossbreds. However, only the purebred cows were included in the study.

Table I shows milk production and herd size in 2002 for the two studied farms, and the corresponding national averages. The milk production levels in the studied herds are below the national average for NRF and above the national average for STN. The herds are furthermore smaller than the national average herd size for dairy cattle, which in 2002 was 15.2 cows.

The herds have been grazing the mountain pastures every summer for more than fifty years, and hardly any new cows have been introduced to the herds, except for self recruitment. These conditions should secure no confounding with background experience in the study.

According to traditional summer farming practise, the cows were kept indoors in a small stanchion barn from the afternoon milking at around 18:00 h, and turned out to the grasslands again after the milking the next morning at around 08:00 h. The cows were fed concentrates according to their milk yield [18], but no roughage was provided in the stanchion barn.

The cows' mean age was 5.8 years in Valdres and 4.4 years in Skåbu, with a span of 3–11 years. The average length of time since last calving was 7.6 months in Valdres and 5.5 months in Skåbu, with a span of 2–11 months. These conditions indicate that no confounding between age of cow, lactation month and breed should be expected.

2.2. Study sites

Information about the climate and location of the two study sites is given in Table II. Climate data are based on data from local weather stations. The climate at both study sites is bio-climatically characterised as the transitional section (OC) between the weak oceanic (O1) and the weak continental (C1) section [27]. This section is characterised by an annual precipitation of 500–800 mm; frost in late spring and in early autumn, and low winter temperatures. This often results in deeply frozen

Table II. Geographical and climatic information about the study sites.

	Valdres	Skåbu
Name of summer farm	Skogstadstølen	Brenden
Municipiality	Vestre Slidre	Sør Fron
Meters above sea level	1 000	935
Vegetation zone (Moen 1999)	Unforested area in the northern boreal veg. zone	Forested area in the northern boreal veg. zone
Climatic zone (Moen 1999)	Transitional section (OC)	
Yearly precipitation	570 mm	600 mm
Yearly mean temperature	–1.7 °C	0.5 °C
Mean temperature in July (Warmest month in the year)	10.2 °C	11.0 °C

References [2, 14, 22, 27].

ground due to thin snow cover. Oceanic plant species are rare, continental species and vegetation types occur [12].

Skåbu is situated in an area with many types of bedrock. The dominating base-rich bedrocks are phyllite, gabbro and leuconorite with a high weathering capacity, giving rise to nutrient-rich soils. Additionally, there are small patches of acid bedrocks such as granite and anortosite, with a lower weathering capacity. Such bedrocks give rise to less fertile soils [38]. In the study area in Valdres, the bedrock consists entirely of a less basic phyllite type [26], and the soils are thus poorer than the base rich soils in Skåbu.

Transhumance (summer dairy farming) has been conducted in both areas for centuries. Numerous livestock herds used to graze these grasslands every summer. However, the total number of dairy herds in Norway has decreased to 2/3 since 1950, with a resulting decline in summer dairy farming. The studied areas today have a very low grazing pressure. The summer farm Brenden in Skåbu is now the only summer farm in this area practising transhumance, and the area is growing over. In Valdres, summer dairy farming is still more common. There are three other grazing herds of cattle and sheep in the surrounding areas of the summer farm Skogstadstølen. With vast grazing areas available, the grazing pressure must still be characterised as low.

The grazing period at both study sites is usually from late June/early July to late August/early September, depending on the weather.

2.3. Grazing value of the recorded vegetation types and plants

Due to the large variation in vegetation types and plant species growing in the semi-natural mountain grasslands and the short and intense growing season with rapid changes in plant composition and growth stage, general nutrient analyses of this kind of vegetation are work intensive and thus scarce. However, in the 1920s Bjor and Graffer [5], Resvoll-Holmsen [33] and Vigerust [43] performed studies on the grazing value of plant species from semi-natural mountain grasslands. In Table III, plant species recorded by Bjor and Graffer [5], Rekdal [32], Resvoll-Holmsen [33] and Vigerust [43] to be of high grazing value are marked with bold print. Bjor and Graffer [5] reported that cattle graze and prefer grass

Table III. Recorded grazed vegetation types at the two study sites and plant species recorded in these vegetation types. The vegetation types in the table are classified after the system of Fremstad [12], and the ones recorded in the table are the following: A4c = Bilbery woodland, bilberry-crowberry st.; *Vaccinium myrtillus – Empetrum nigrum* coll. woodland. C2a = Tall-herb – downy birch st.; Tall-herb *Betula pubescens* spp. *pubescens* st. woodland. C2c = Low-herb st. scattered with tall herb woodland. G3 = Tufted hair-grass grassland; *Deschampsia cespitosa* grassland. G4 = Common bent – red fescue – sweet vernal-grassland; *Agrostis capillaris – Festuca rubra – Anthoxanthum odoratum* grassland. G4c = Alpine cat's-tail – meadow-grass st.; *Phleum alpinum – Poa pratensis* ssp. *alpigena* st. grassland. G5b = Mat-grass – alpine lady's-mantle; *Nardus stricta – Alchemilla alpina* st. grassland. G8 = Intermediate/dry medium base-rich lowland grassland. Lawn = Cultivated areas around new cottages in the area. The notations X, C and D code for the observed amount of the species within the recorded vegetation type, where X = more scarcely found, C = common, D = dominating. The species in bold print are recorded to be important grazing species in semi-natural mountain pastures [5, 32, 33, 43].

	Grazed vegetation types in Skåbu				Grazed vegetation types in Valdres		
Recorded species	A4c	C2a/C2c	G4/G8	Lawn	A4c	G3	G4c/G5b
Bushes, heather and trees							
Betula nana ssp. *nana*	X				X		X
Juniperus communis ssp. *communis*	X	C	X		C		X
Rubus idaeus		X					
Rubus saxatilis		X					
Salix caprea* ssp. *caprea		X					
Salix herbacea							X
***Salix* spp.**	X	X	X			X	X
Arctostaphylos uva-ursi		X					
Calluna vulgaris			X				X
Empetrum nigrum coll.	X	X			D		X
Vaccinium myrtillus	D	X	X		D		X
Vaccinium uliginosum ssp. *uliginosum*	X	X	X		X		X
Vaccinium vitis-idaea	X	X	X		D		X
***Betula pubescens* coll.**	D	C	X				
Betula pubescens* ssp. *czerepanovii					D		
Picea abies ssp. *abies*	X	X			X		
Pinus sylvestris var. *sylvestris*	X	X					
Sorbus aucuparia* ssp. *aucuparia					X		
Graminides							
Agrostis capillaris	X	X	X	C			X
Alopecurus geniculatus							X
***Anthoxanthum odoratum* coll.**	X	X	X		X		C
Avenella flexuosa	D	C	X	C	D		X
Avenula pubescens		X	X				
Deschampsia cespitosa* ssp. *cespitosa	X	C	C			D	C
Festuca ovina* ssp. *ovina	X		X		X		X
Festuca rubra* ssp. *rubra	X		X	C			X
Melica nutans	X	X					
Nardus stricta		X	X		X		C (G4c) D (G5b)
Phleum alpinum		X	C			X	C
Phleum pratense* ssp. *pratense		X					
Poa alpina* var. *alpina			X				C
***Poa* spp.**	X				X	X	X
Carex bigelowii* ssp. *bigelowii		X					X
Carex brunnescens ssp. *brunnescens*.			X				X

Table III. Continued.

Recorded species	Grazed vegetation types in Skåbu A4c	C2a/C2c	G4/G8	Lawn	Grazed vegetation types inValdres A4c	G3	G4c/G5b
Carex capillaris ssp. *capillaris*			X				
Carex nigra* var. *nigra		X	X				X
Carex pallescens			X		X		X
Carex panicea							X
Carex vaginata							X
Eriophorum vaginatum							X
Juncus filiformis			X				X
Luzula multiflora ssp. *frigida*	X		X		X	X	C
Luzula pilosa	X	X	X		X		
Luzula spicata							X
Herbs							
Achillea millefolium* ssp. *millefolium		X	X		X	X	X
Aconitum lycoctonum ssp. *septentrionale*		C				X	X
Alchemilla alpina			X		X	C	D
***Alchemilla* spp.**		X	X			X	X
Angelica sylvestris		X					
Antennaria alpina ssp. *alpina/A. dioica*.	X	X	X		X		X
Astragalus alpinus coll.		X	X				
Bartsia alpine		X	X				
Bistorta vivipara	X	X	X		X	X	C
Botrychium lunaria			X				
Campanula rotundifolia ssp. *rotundifolia*		C	X			X	X
Cerastium cerastoides							X
Cerastium fontanum ssp. *vulgare*			X				X
Cicerbita alpina		X					
Cirsium heterophyllum		X					
Coeloglossum viride			X				
Dactylorhiza fuchsii			X				
Equisetum hyemale		X					
Equisetum sylvaticum	X	X					
Erigeron borealis			X				
Euphrasia wettsteinii		X	X				X
Euphrasia stricta coll.			X				
Filipendula ulmaria		X	X				
Galium boreale			X				
Gentiana nivalis			X				
Gentianella campestris ssp. *campestris*		X	X				
Geranium sylvaticum	X	C	X		X	X	
Geum rivale	X	X					
Gymnocarpium dryopteris					C		
Hieracium lactucella			X				
***Hieracium vulgatum* coll.**					X		
Knautia arvensis			X				
Leontodon autumnalis	X	X	C			X	C
Lycopodium annotinum ssp. *annotinum*					X		
Maianthemum bifolium					X		
Melampyrum pratense	X	X			X		
Melampyrum sylvaticum					X		
Moneses uniflora		X			X		
Myosotis spp.		X					
Omalotheca norvegica						X	
Oxalis acetosella		X					

Table III. Continued.

	Grazed vegetation types in Skåbu				Grazed vegetation types inValdres		
Recorded species	A4c	C2a/C2c	G4/G8	Lawn	A4c	G3	G4c/G5b
Parnassia palustris	X		X				
Pedicularis lapponica		X					
Plantago media			X				
Potentilla crantzii			X				X
Potentilla erecta			X		X		X
Primula scandinavica			X				
Prunella vulgaris							X
Pulsatilla vernalis			X				
Pyrola minor		X	X				
Pyrola norvegica		X	X				
Ranunculus acris coll.	X	X	X		X	X	X
Rhinanthus minor coll.		X	X				
Rumex acetosa* ssp. *acetosa	X	X	X		X	X	X
Sagina saginoides							X
Saussurea alpina		X	X				
Selaginella selaginoides			X				
Sibbaldia procumbens			X				X
Silene dioica		X					
Silene vulgaris	X		X				
***Solidago virgaurea* coll.**	X	X	X		X		
***Taraxacum* spp.**		X	X				X
Thalictrum alpinum		X	X				
Trientalis europaea	X	X			C		X
Trifolium hybridum* ssp. *hybridum				C			
Trifolium medium			X				
Trifolium pratense			X	C			
Trifolium repens		C	C			X	C
Trollius europaeus		X					
Urtica dioica ssp. *dioica*		X	X			X	X
Valeriana sambucifolia ssp. *sambucifolia*		X					
Veronica alpina ssp. *alpina*							X
Veronica officinalis			X				X
Veronica serpyllifolia ssp. *serpyllifolia*						X	X
Vicia cracca			X				X
Viola biflora		X	X			X	X
Viola canina coll.					X		
Viola riviniana		X					
Viola sp.			X				

in general, and especially species such as *Agrostis capillaris*, *Anthoxanthum odoratum* coll., *Deschampsia cespitosa* ssp. *cespitosa, Avenella flexuosa and Festuca ovina* ssp. o*vina*. In addition to grass, sedges (*Carex* spp.) and herbs are recorded to be preferred grazing plants. Studies by Garmo [16, 17] state that sedges (*Carex* spp.) collected in July and August on mountain grasslands in Norway, have a higher content of crude protein and less crude fibre than grass species during the entire grazing season. The results from Garmo [16, 17] thus indicate that sedges in general have a higher nutrient value than grass.

One plant species to be mentioned in addition to the preferred grazing species is *Nardus stricta. Nardus stricta* is not regarded as a valuable or preferred grazing species, due to low digestibility and stiff straw-like leaves. Still, *Nardus stricta* is known to be grazed to a certain extent, maybe due to the easy accessibility in the grasslands dominated by the species [35].

2.4. Recording procedures

Two technicians followed each herd during the daily grazing period and collected faeces samples, took notes about the grazing areas' botanical composition, made brief descriptions of the recorded vegetation, and marked out if the herds stopped for grazing or just walked through the different vegetation types. Also the technicians recorded various activities of the cows every ten minutes. The results of these recordings are presented by Sæther et al. [41]. The recording period was in week 28 (July) and 32 (August) in Valdres and week 29 (July) and 33 (August) in Skåbu. The herds were observed from 08:00 h, after the morning milking, to approximately 16:00 h when the herds returned without escort to the stanchion barn for the evening milking at 18:00 h. On average, the herds were observed 9.1 hours in Valdres and 8.8 hours in Skåbu, with a span of 6.8–11.5 hours per day.

The vegetation descriptions and maps, see Figures 1 and 2, are based on four-days of fieldwork by this study's botanist during the first recording week early in July, supplied with vegetation data recorded by the technicians. The botanist followed the herds during two days at each study site and recorded all observed plant species on the areas where the herds stopped for grazing. In addition, the regrowth situation, grazing pressure, if the areas had been fertilised, surrounding vegetation etc. were noted. Some areas pointed out by the cattle owners as preferred grazing areas were included, even if these areas were not grazed during the four-day fieldwork. The lists of observed plant species were then transformed into forms and used by the technicians for their daily recordings in the areas where the herds stopped for grazing. The nomenclature followed Lid and Lid [24]. Finally, all botanical data were converted into vegetation types according to the system of Fremstad [12]. In the further vegetation descriptions, codes in brackets refer to the system of Fremstad [12], which is one of two prevailing systems for vegetation mapping in Norway. It is also the most differentiated regarding semi-natural grasslands. The amount of recorded plant species within each vegetation type was classified into three levels, "only scarcely found", "common" or "dominating", a classification recommended by Elven (personal communication) when making more sketch alike vegetation descriptions.

The global positioning system (GPS) unit, a Magellan GPS 315, was used to track the grazing cattle. Magellan GPS 315 has a position accuracy of +/− 7 metres. The bell cow (an efficient leader) in each herd wore a GPS receiver during the recording period, collecting data about the daily walking route chosen by the respective herd. The receiver was mounted to the

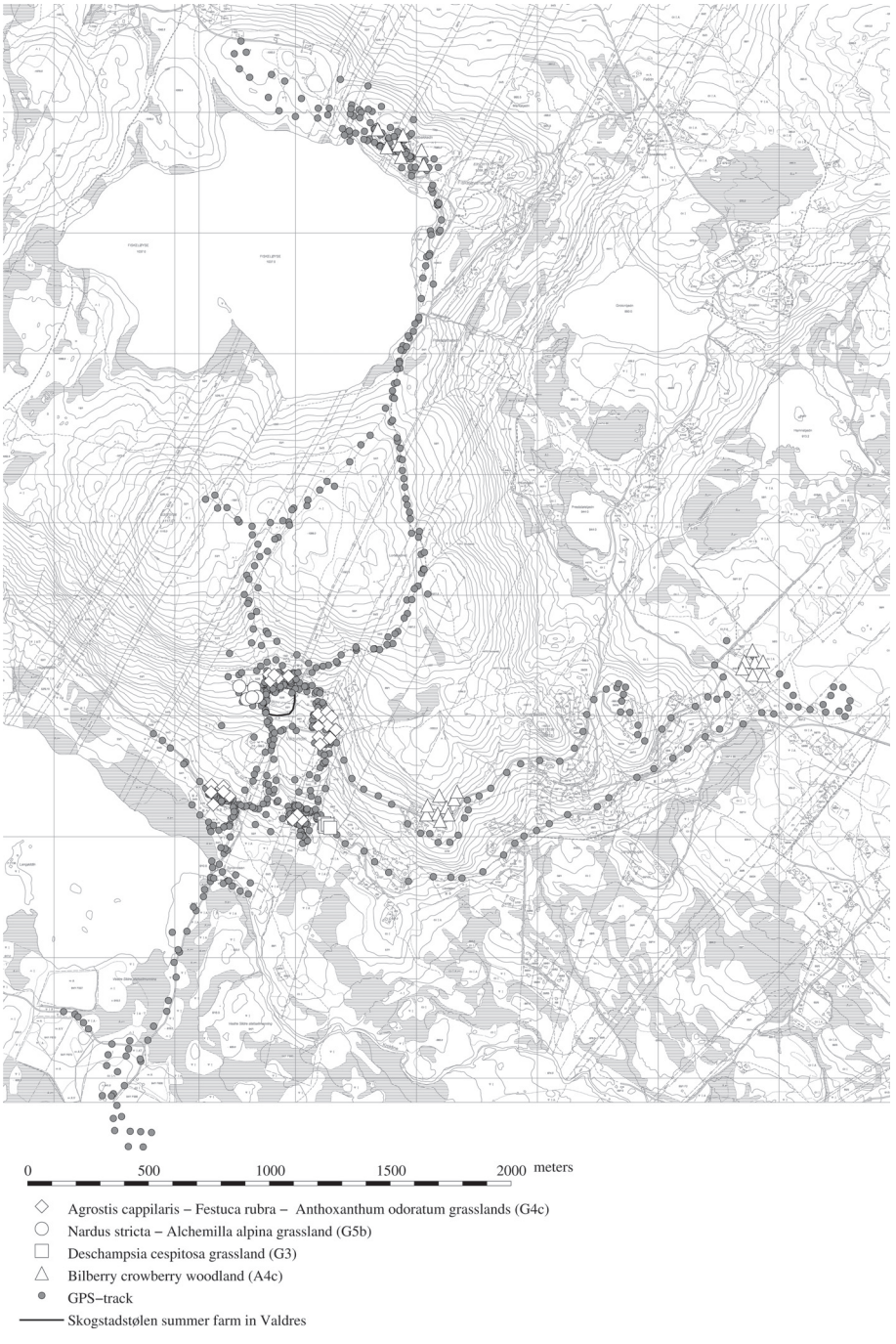

Figure 1. Map over Skogstadstølen summer farm in Valdres, showing the GPS tracks and some of the localisations of the described vegetation types.

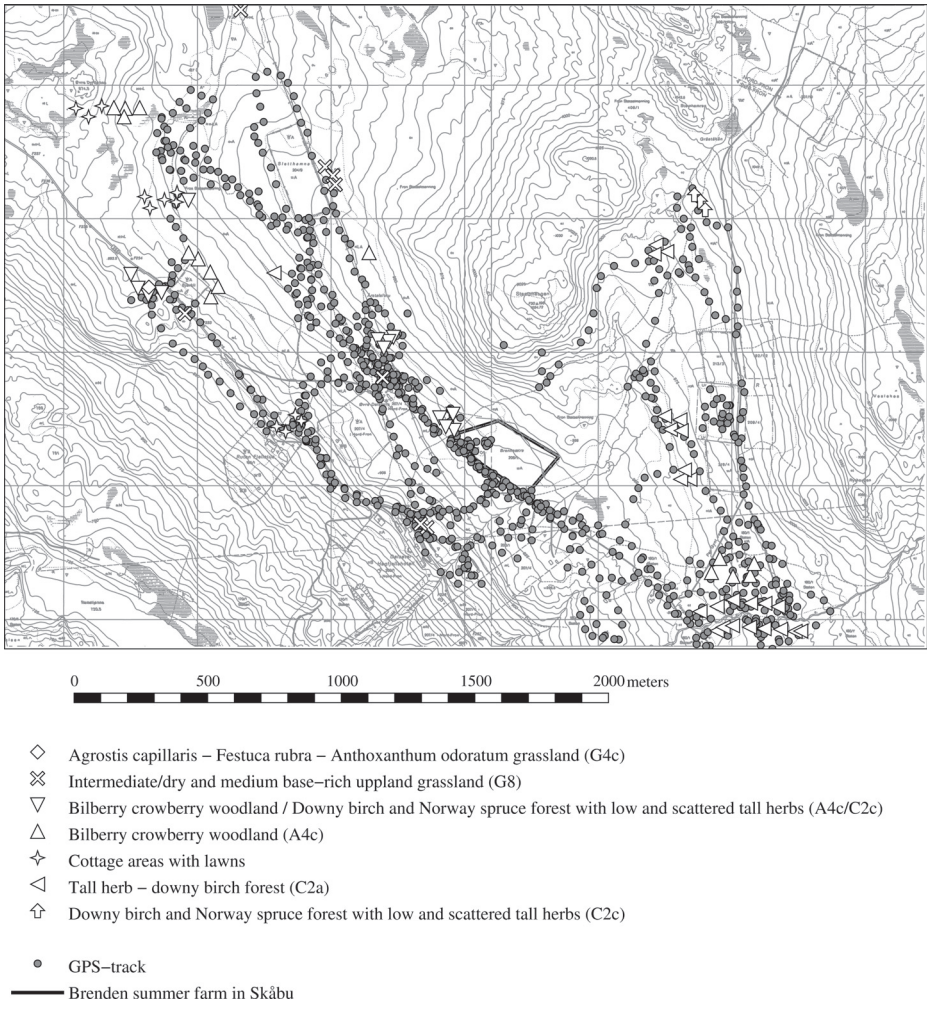

Figure 2. Map over Brenden summer farm in Skåbu, showing the GPS tracks and some of the localisation of the described vegetation types.

collar of the bell cow while she was still in the box during milking time in the morning and taken off in the box after she had returned in the afternoon. As the cow moved, the unit logged the geographical position. The data points were collected when the cow had moved a certain distance, and do thus not indicate the length of time spent by the herd on a given area, but merely provide a record of their movement pattern. The data collected was transferred to a PC at the end of each day. The data from all days were later integrated in the GIS (Geographical Information System), making it possible to analyse and present the movements of the cows on a map.

2.5. Microhistological analyses

Faeces samples were collected during the daily grazing periods, picked up just

after the cows had deposited them. They were labelled with the cow's ID and date and hour of collection. When still warm they were put in a cooling bag, and every evening the day's samples were put in a freezer (−18 °C), where they were stored until analysis. In Skåbu, 14 faeces samples from each breed were collected, and in Valdres, 10 faeces samples from STN and 11 faeces samples from NRF were collected. In total, 49 faeces samples from 20 different cows were collected.

The faeces samples were prepared for microhistological analyses, following the procedures of Garcia-Gonzalez [15]. After thawing, about 1 tablespoon was lightly ground in a mortar. About 1 mL of each sample was placed in a test tube with 4 mL concentrated nitric acid. The tube was placed in a boiling water bath for 1 minute. Then the sample was diluted with 200 mL water and boiled for another 4 minutes. The suspension was passed through 1.00 and 0.20 mm sieves and rinsed with water. The 0.20 mm fraction was conserved in a mixture of 85% ethanol (70%); 10% formalin (40%) and 5% glacial acetic acid. The fragments were dispersed on microscope slides in a 50% aqueous solution of glycerine. Cover-slips (20 × 40 mm) were then fixed to the slides and sealed with nail varnish. Two slides from each sample were prepared and analysed, labelled as an "a" and "b" test, and the means from these two tests were used in further statistical treatment of the data.

All fragments intersecting a 1 mm wide line along 40 mm long transects were examined. The transects were placed 3 mm apart. A minimum of 200 plant fragments was identified on each slide.

The concern of varying digestibility of the plants is a topic of debate, and there is literature both to support and refute its impact on microhistology. This debate is found to be of minor importance in this study, since the main task is to identify possible differences in plant and vegetation preferences between two breeds when grazing in the same vegetation, and there is no reason to believe that the digestibility of the plants is different in the two breeds. The results from the microhistological analyses were used in this study to compare the two breeds on the basis of remaining and identified fragments and vegetation maps.

2.6. Plant species, plant genera and plant groups used in statistical analysis

The 49 faeces samples were analysed for fragments from 25 plant species and plant genera, total fragments and total fibres. In addition to these 25 plant species and plant genera, four plant groups were constructed, these are the following:

(1) Total grass = *Deschampsia cespitosa, Avenella flexuosa*, *Festuca rubra* ssp. *rubra*, *Festuca ovina* ssp. *ovina, Festuca* spp., *Poa* spp., *Molinia caerulea, Agrostis* spp., *Anthoxanthum odoratum* coll., *Phleum alpinum*, *Nardus stricta*, *Melica nutans*, *Alopecurus geniculatus*, unidentified grass species.

(2) Total fescue = *Festuca rubra* ssp. *rubra*, *Festuca* ssp. *ovina, Festuca* spp.

(3) Total bushes = *Salix* spp., *Juniperus communis*.

(4) Total heather = *Vaccinium myrtillus, Calluna vulgaris*.

2.7. Statistical model

In the statistical analysis the possible effects of breed (STN and NRF), farm (Skåbu and Valdres) and month (July and August) were included as fixed effects together with the interaction breed * farm. The effect of cow within breed was included as a random effect to adjust for variation between individuals within breed.

The PROC MIXED procedure in the SAS program (SAS system for windows,

V8) was used for the statistical analysis, according to the following model:

$$y_{ijkl} = \mu + breed_i + farm_j + month_k + farm*breed_{ij} + cow_l(breed_i) + e_{ijklm}$$

where y denotes the percentage of each plant species, plant genera or plant group from the total of observed fragments in the faeces samples.

μ = verall mean.

$breed_i$ = fixed effect of breed i (i = 1,2).

$farm_j$ = fixed effect of farm (j = 1,2).

$month_k$ = fixed effect of month (j = 1,2).

$farm*breed_{ij}$ = interaction of farm$_j$ and breed$_i$.

$cow_l(breed_i)$ = random effect of cow$_l$ within breed$_i$.

e_{ijkl} is the effect of error term of the fixed effects breed$_i$, farm$_j$, month$_k$, the interaction between farm$_j$ and breed$_i$, and the random effect of cow$_l$ within breed$_i$.

3. RESULTS

3.1. Vegetation descriptions

The recorded plant species and grazed vegetation types in Valdres and Skåbu are listed in Table III. The species in bold print are recorded to be important grazing species in semi-natural mountain pastures [5, 32, 33, 43].

Both study sites have species rich grasslands. The vegetation in Valdres is, however, mainly characterised by common grassland species, while the vegetation in Skåbu is characterised by many base demanding species. In total, 123 species were found at the two sites. Amongst these, 51 species were only found in Skåbu and 20 were only found in Valdres (Tab. III).

The recorded occurrence of some of the plant species within the same vegetation type varies between Skåbu and Valdres, see Table III. *Juniperus communis* ssp. *communis, Empetrum nigrum* coll. and *Vaccinium vitis-ideae* are all recorded only as "more scarcely occurring" in the Bilberry woodland, bilberry-crowberry woodland (A4c) vegetation in Skåbu, whereas the same vegetation types in Valdres are recorded as "common" or "dominating" species. This variation within a vegetation type is explained by the fact that vegetation types according to Fremstad [12] are quite broadly defined, and therefore include variation regarding occurrence and frequencies of different plant species due to local conditions.

The GPS data from Valdres cover approximately 18 km^2. This area contains many small patches of grassland close to summer farms or former summer farms, which are now often used as mountain cabins. Heaths often surround the grassland patches. The terrain is relatively hilly and undulating, resulting in varying ecological conditions within the grasslands. Due to lack of forests in the near surroundings of the summer farms, small elevations and knolls are more exposed to wind and drought, thus further enhancing the small-scale differences in the grazed areas.

The most common grassland vegetation type in Valdres is *Agrostis cappilaris – Festuca rubra – Anthoxanthum odoratum* grasslands on intermediate nutrient rich bedrock (G4c) (Tab. III). This vegetation type is characterised by many common and small-sized grasses and herbs with low to medium demands of base rich soil. The distribution of the species within the grassland is not even. *Nardus stricta* and other drought-resistant species often grow on the top of small elevations, while species indicating better moisture conditions, e.g. certain *Carex* species, dominate on lower and more humid parts of the grasslands. *Vaccinium myrtillus* was also often found here. Another grassland type in the Valdres area is dominated by *Nardus stricta* as a result of too heavy grazing for many years. It is classified as *Nardus stricta – Alchemilla alpina* grasslands (G5b) and contains many of the same species as G4c.

The grasslands in Valdres are often surrounded by *Juniperus communis – Betula nana* heath, poor subtype (S2a), a secondary vegetation type after deforestation of A4c in the north-boreal vegetation zone. S2a is not described any further since this vegetation was hardly grazed. The study area also contains *Betula pubescens* ssp. *czerepanovii* woodland of *Vaccinium myrtillus – Empetrum nigrum* coll. type (A4c) with large amounts of *Avenella flexuosa* in the field layer (Fremstad [12]).

The investigated area around Brenden in Skåbu covers approximately 8 km^2. The terrain here is less hilly and undulating than in Valdres. Thus, moisture conditions in the grasslands are more uniform, which also gives a more uniform distribution of plant species. Forests, protecting small elevations and knolls against wind and drought, surround the grasslands.

The grasslands in Skåbu are semi-dry to dry and medium base-rich upland grasslands (G8). They are grass and herb rich with many base-demanding species in addition to common meadow species. Some base-demanding species recorded here are *Astragalus alpinus* coll., *Gentiana nivalis* and *Primula scandinavica.* Species that characterise *Agrostis cappilaris – Festuca rubra – Anthoxanthum odoratum* grassland (G4) such as *Carex pallescens, Carex brunnescens* ssp. *brunnescens*, *Carex nigra* var. *nigra, Avenella flexuosa* and *Phleum alpinum*, however, also occur in this grassland type in Skåbu. The "lawns" around the cabins contain *Avenella flexuosa, Agrostis cappilaris* and cultivated species of *Festuca rubra* and *Trifolium hybridum*. Woodlands with *Betula pubescens* coll. and *Pinus sylvestris* ssp. *sylvestris*, classified as nutritious-rich types of bilberry-crowberry woodlands with a low-herb field layer scattered with tall herbs (A4c/C2c) cover certain parts of the area. The field layer in the woodlands also contains many of the species found in the open pastures and meadows, and *Deschampsia cespitosa, Avenella flexuosa* and *Geranium sylvaticum* occur frequently here. A bush layer of *Juniperus communis* and *Betula nana* sometimes occurs in dry/semi-dry parts (A4c) of the forests and various *Salix* species in moister/wet parts (C2c). Tall-herb – *Betula pubescens* ssp. *pubescens* forest (C2a) is found along small streams and other wet parts of the forest. Tall herbs occurring here are among others *Aconitum lycoctonum* ssp. *septentrionale, Cicerbita alpina, Cirsium helenoides, Geranium sylvaticum* and *Trollius europaeus*. The most common grass species are *Deschampsia cespitosa* and *Avenella flexuosa*.

3.2. Daily walking patterns

The GPS recorded an average daily walking distance for the herd of 7.3 km in Valdres and 8.0 km in Skåbu. The GPS tracks in Figure 1 and Figure 2 show the daily walking routes of the herds. Note that the cows mainly walked along roads and paths, hardly making any short cuts through the terrain.

In Valdres, the cattle had to walk through the *Juniperus communis-Betula nana* heaths to either get to the small patches of grasslands near the summer farm or to the *Betula* forests which were 2–3 km from the summer farm, see Figure 1. The field observations show that the cows, as a rule, did not stop for grazing on their way to the grazing areas.

In Skåbu, the grasslands, cabin lawns and the rich forest types in the near surroundings of the summer farm are good grazing areas. However, instead of just freely roaming around in these rich grazing areas, the GPS data (see Fig. 2) show that the cattle mainly followed established tracks within a radius of 1–2 km from the summer farm, and the technicians recorded that they grazed along these walking routes. This is in contrast to the grazing

Table IV. The figures for the plant species, plant genera and plant groups are given as percentage of total fragments. The figures for "total fragments" and "total fibres" are actual findings.

Plant species, plant genera or plant group	Mean	Plant species plant genera or plant group	Mean (std dev)
Birch, *Betula* spp	0.99 (1.38)	Matgrass *Nardus stricta*	3.82 (3.06)
Hedge apple, *Salix* spp.	0.41 (0.72)	Mountain melic *Melica nutans*	0.06 (0.18)
Blueberry, *Vaccinium myrtillus*	2.03 (1.26)	Water foxtail *Alopecurus geniculatus*	0.09 (0.23)
Heather, *Calluna vulgaris*	2.13 (1.45)	Unidentified grass *Graminae*	12.80 (3.00)
Juniper, *Juniperus communis*	0.48 (0.50)	Sedge species *Carex* spp.	8.36 (6.16)
Tufted hair-grass, *Deschampsia cespitosa*	25.54 (9.39)	Horsetail *Equisetum* spp.	0.26 (0.33)
Wavy hair-grass, *Avenella flexuosa*	15.08 (7.57)	Club moss *Lycopodium* spp.	0.01 (0.04)
Red fescue, *Festuca rubra*	3.24 (2.19)	Moss *Bryophyta*	0.75 (0.62)
Sheep's fescue, *Festuca ovina*	0.54 (1.59)	Herbs	8.37 (5.01)
Unidentified fescue, *Festuca* spp.	7.04 (3.32)	Lichen *Lichenes*	0.03 (0.07)
Meadow grass, *Poa* spp.	3.46 (2.05)	Total grass	76.13 (5.84)
Moor grass, *Molinia caerulea*	0.30 (0.39)	Total fescue	10.83 (4.88)
Bent-grass, *Agrostis* spp.	2.55 (1.77)	Total bushes	0.88 (0.95)
Sweet vernal gras, *Anthoxanthum odoratum*	0.08 (0.24)	Total fragments	229.60 (17.27)
Alpine timothy, *Phleum alpinum*	1.53 (0.88)	Total fiber	314.91 (57.28)

std dev: Standard deviation.

pattern in Valdres, where the cattle usually did not stop along their walking route. The herd's preference to follow roads and paths in Skåbu results in longer daily walking distances than in Valdres, despite the occurrence of very good grazing areas in the vicinity of the summer farm.

3.3. Results from the microhistological analyses

Table IV shows the mean values for all plant species, plant genera and plant groups observed in the faeces samples. The cows had most fragments from grass (76%), distributed among 13 recognised species and genera in addition to a group of unidentified grass species (*Graminae*). The two single species with the highest share of observed fragments are *Avenella flexuosa* (25%) and *Deschampsia cespitosa* (15%) which agrees well with the recorded easy access to these species in the area and these species' generally accepted high grazing value. Herbs and *Carex* spp. in general are valuable grazing plants and together they contribute to almost 16% of the observed fragments. Another 6% of the fragments come from the Heather group and the Bushes group.

Plant species, plant genera and plant groups with less than 2% total mean values for observed fragments are neither further commented nor included in further statistical analysis. This was due to the fact that they contributed very little to the total amount of observed plant material and had minor effects on the analytical results, even if some of them are considered to be of great grazing value, i.e. *Salix* spp., *Festuca ovina, Anthoxanthum odoratum* and *Phleum alpinum* [5, 32, 33, 43].

Table V presents the results from the statistical model, showing that the effect of study site is significant for all the plant species, genera and groups tested in the model, whereas only month has a significant ($P < 0.01$) effect on *Avenella flexuosa*, *Poa* spp. and *Agrostis* spp., indicating that these plant species and genera are grazed differently in July and August. Fewer fragments of *Avenella flexuosa* and *Agrostis* spp. were observed in July (12.0% and 1.9% respectively) than in August (18.0% and 3.7% respectively). *Poa* spp. had an opposite trend, since the percentages of observed fragments in July were 4.1%, compared to 2.4% in August.

The effect of breed was only significant for the plant species *Nardus stricta,* for which the STN breed had a higher share of fragments in the faeces samples than the NRF breed (Tab. V). The interaction between farm and breed was significant for *Vaccinium myrtillus* ($P < 0.05$) and the plant group "total grass" ($P < 0.01$). When testing the two study sites separately, no significant effect of breed was found at Skåbu. However, in Valdres, NRF had significantly ($P < 0.05$) more fragments of *Vaccinium myrtillus* than STN, and STN had a tendency ($P = 0.060$) of more *Nardus stricta* fragments than NRF.

Figure 3 illustrates the LS-means in observed fragments for the breeds by farm, indicating tendencies to interaction for the plant group "Total grass species", the plant species *Vaccinium myrtillus* and *Nardus stricta,* and finally the plant genera *Carex* spp. These illustrations are chosen because they together contribute to a picture of possible differences in plant and vegetation preferences of the two breeds STN and NRF.

4. DISCUSSION

4.1. Possible breed differences in plant and vegetation preferences

This study intended to study if different selection history for high milk production in two cattle breeds influences the animals' plant and vegetation preferences in a way that affects the management of the biodiversity in semi-natural grasslands.

In general, semi-natural mountain grasslands are regarded as extensive grazing areas, in the meaning that the animals must make more of an effort when searching for fodder that will satisfy their hunger and nutrient requirements. This is in contrast to grazing on cultivated pastures where the plant species are carefully selected to give the grazers easy access to fodder with a high nutrient value. The semi-natural mountain grasslands in this study are characterised by great diversity of vegetation types and plant species, enabling the animals to choose which vegetation they prefer to graze. Only the vegetation types that were actually grazed by the cows are described and mentioned in this study, and they are all valuable grazing areas [32].

The distribution of species within the grasslands and the representation in the faeces samples are more uniform in Skåbu than in Valdres (Tab. V). Furthermore, the present study shows some tendencies of differences in plant and vegetation preferences of the two breeds STN and NRF (Fig. 3, Tab. V). Differences in observed plant fragments in faeces samples from plant species, plant genera and plant

Table V. Results from the statistical analyses on the plant fragment residues observed in the faeces samples. The figures for the plant species, plant genera and plant groups are given as percentage of total fragments. The figures for "total fragments" and "total fibres" are actual findings. Figures in bold print are significant values.

Plant species, genera or group	Farm	Breed	Month	Interaction Farm/breed	LS-means		LS-means	
					STN	NRF	Skåbu	Valdres
Blueberry *Vaccinium myrtillus*	**			*	1.84	2.09	**2.63**	**1.29**
Heather *Calluna vulgaris*	**				1.93	2.06	**3.16**	**0.83**
Tufted hair-grass *Deschampsia cespitosa*	**				26.99	25.13	**19.25**	**32.87**
Wavy hairgrass *Avenella flexuosa*	**		**		15.00	14.94	**19.75**	**10.20**
Red fescue *Festuca rubra*	**				0.42	0.43	**4.10**	**1.55**
Unidentified fescue *Festuca* spp.	**				6.32	7.86	**8.96**	**5.23**
Meadow grass *Poa* spp.	*		**		3.80	2.95	**2.79**	**3.96**
Bent grass *Agrostis* spp.	*		**		2.76	2.70	**3.29**	**2.17**
Matgrass *Nardus stricta*	**	*			**5.08**	**3.76**	**1.69**	**7.15**
Unidentified grass *Graminae*	**				12.91	12.95	**11.46**	**14.40**
Sedge species *Carex* spp.	**				8.39	9.47	**4.41**	**13.45**
Herbs	**			**	7.66	7.53	**11.69**	**3.50**
Total grass	**		*		77.68	75.80	**74.04**	**79.43**
Total *Festuca*					9.17	10.66	**13.35**	**6.49**
Total fragments			**		232	229	227	235
Total fibers					312	333	334	312

** 1%, * 5%.

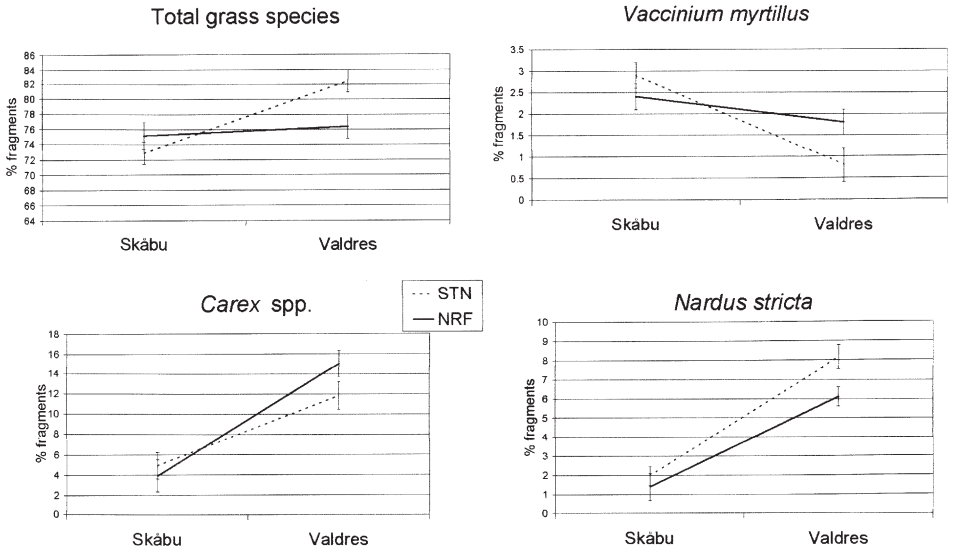

Figure 3. Illustrations of LS-means in observed fragments for the breeds by farm for four of the tested plant species/genera/groups. Relevant *P*-values: Total grass species: interaction between farm and breed ($P = 0.010$), *Vaccinium myrtillus*: interaction between farm and breed ($P = 0.036$), breed difference in Valdres ($P = 0.038$), *Nardus stricta*: breed difference when farms are tested together ($P = 0.052$), tendency to breed difference in Valdres ($P = 0.060$), *Carex* spp.: tendency to interaction between farm and breed ($P = 0.115$). There are significant differences between farms ($P < 0.01$) for all four plant species/genera/groups.

groups are available indicators of possible differences of chosen vegetation types between the two breeds. Since the herds to a certain extent spread while grazing and the patches of the different vegetation types might be rather local, the cows still have the possibility to choose different vegetation types and plant species if they desire – even if grazing in herds.

The results presented in Figure 3 indicate that when grazing in areas with quite nutrient- and base-rich soil and species-rich vegetation types, as in Skåbu, the two breeds graze the same vegetation and plant species. In Valdres, however, where the soil is less fertile, the plant species diversity is lower and the plant species distribution less uniform than in Skåbu, the results indicate that the NRF cows graze more in patches where *Carex* spp. grow than the STN cows. STN also graze more *Carex* spp. in Valdres than in Skåbu, but the increase is less than for NRF. Both breeds graze less *Vaccinium myrtillus* in Valdres, but since NRF decrease less than STN and since *Vaccinium myrtillus* occur in the same vegetation type as *Carex* spp. in Valdres, this indicates that NRF cows graze more in patches where *Carex* spp. grow and *Vaccinium myrtillus* occur. Both breeds graze more *Nardus stricta* in Valdres than in Skåbu, but STN has a higher increase than NRF, indicating that the STN cows graze more in nutrient poor areas where *Nardus stricta* is common in Valdres than NRF.

4.2. Nutrient value as an indication of different vegetation preferences

The results from the statistical analysis show significant interaction between

breed and farm for the plant group "total grass species". Figure 3 shows that both breeds graze more grass in Valdres than in Skåbu, however, STN increases its amount of fragments from grass more than NRF – thus giving rise to the question: What do NRF cows eat in Valdres? The only analysed plant species/genus that gives a corresponding picture to the interaction between farm and breed for "total grass species" is the *Carex* spp. genus. The content of *Carex* spp. in the faeces samples, which was around 12–14% in Valdres, indicates that the cows selectively grazed these species, probably at the expense of grass species. Thus, the tendency of replacing grass with *Carex* spp. seems to be higher in NRF than STN. The nutrient poorer soil conditions and the lower plant species diversity in Valdres may explain NRF's preferences to *Carex* spp. at the expense of grass, since *Carex* spp. compared to grass have a better nutrient value [16, 17]. In addition *Carex* spp. are more common species, and thereby more available, in Valdres than in Skåbu.

Vaccinium myrtillus is recorded with just about 2% in the faeces samples. Earlier studies [5, 43] have shown that *Vaccinium myrtillus* is grazed only in small amounts compared to grasses. The low percentage may indicate that it is not deliberately grazed, but eaten almost by accident when grazing surrounding vegetation. The significant differences between breeds for fragments of *Vaccinium myrtillus* in Valdres may support the conclusion that NRF grazes more in vegetation where *Carex* spp. grows than STN, since *Vaccinium myrtillus* also occurs in such plant communities.

The differences between the breeds, independent of study site, are significant only for *Nardus stricta* (Tab. V). The STN breed has the highest share of fragment residues of this species. As mentioned earlier, *Nardus stricta* is not regarded as a valuable or nutrient rich grass species, its only advantage in vegetation types as G4c and G5b is that it is very common and thereby easily accessible. When STN graze this species more than NRF, it might be an expression of not being so concerned about grazing the most nutrient rich vegetation, simply because the breed's nutrient requirements are still satisfied when grazing vegetation with relatively high shares of *Nardus stricta.*

5. CONCLUSION

This study shows that a cattle breed selected for high yield, thus having a higher demand for nutrient rich fodder, seems to prefer to graze the most nutrient rich species (i.e. preferring *Carex* spp. over grass species) compared to a lower yielding cattle breed, when grazing on shared, not especially nutrient, base or species rich grasslands.

When grazing semi-natural mountain grasslands, the lower yielding cattle breed Blacksided Trønder and Nordland Cattle (STN) grazes significantly more *Nardus stricta*, a less nutrient rich grass species, than the moderate yielding cattle breed Norwegian Red (NRF).

When managing semi-natural grasslands, the effect of grazing the vegetation might be different when choosing a low instead of a moderate yielding dairy cattle breed. This possible difference ought to be taken into consideration since loss of biodiversity by re-growth of less nutrient rich vegetation types seems to be smaller when using a lower yielding breed.

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