1. General Introduction

Temperate semi-natural grasslands, which are forming a large part of the biodiversity of the European agricultural landscape (Isselstein *et al.* 2005) are an important biodiversity resource (Pärtel *et al.* 2005). The proportion of such valuable grasslands in the European Union declined during the last 50 years (Rook *et al.* 2004). Intensification and abandonment threatens the remaining areas. To maintain grassland for nature conservation, a large proportion of the herbage grown has to be removed (Jefferson and Robertson 2000). Removal of herbage and maintenance may be realised by grazing, as semi-natural grasslands were developed through agricultural systems such as pasturing (Spatz 1994). However, the number of the main agriculturally important grazers (cattle and sheep) declined during the last decade (EUROSTAT 1992-2002), possibly leading to a lack of animals able to maintain such valuable grassland. To prevent a further reduction of both biodiverse grassland and the number of animals able to maintain it, systems enabling biodiversity maintenance and agricultural production have to be developed (Isselstein *et al.* 2005).

Grazing is the most important process to compound the spatial variability of quantity and quality of herbage on natural grassland (O'Reagain and Schwartz 1995). Thus, both grassland biodiversity and animal production might benefit from grazing. Grazers create and maintain a patchy sward structure by grazing selectively (Coughenour 1991), and in contrast to fertilisation, they supply nutrients irregularly (Spatz 1994). By grazing grassland at a low stocking density, its biodiversity can be maintained and increased (Adler *et al.* 2001, Bakker 1989) and its structural complexity is influenced (Tallowin *et al.* 2005). As it is nutritionally beneficial for the grazing animal to graze selectively (Phillips 2002) and in a patchy pattern (Cid and Brizuela 1998), even less productive grassland might be used for efficient livestock farming with reduced stocking (Isselstein *et al.* 2005). Besides their selectivity of grazing, animals kept on such grassland have to be able to take in large amounts of herbage. As steers are characterised by relatively low nutritional requirements and a large intake capacity (Steinwidder 2003) extensive grazing systems might be established by keeping steers for fattening purposes.

Combining biodiversity-targeted management and agricultural production needs a deeper insight into the relation between grazing animal and sward. As there are major gaps in knowledge of grazing behaviour in biodiverse pastures (Rook and Tallowin 2003), and as efficient production systems utilising such grassland have to be found (Isselstein *et al.* 2005), this study investigates the integration of both.
Therefore, steers of different breeds were allowed to graze on heterogeneous and biodiverse grassland at different stocking densities. It should be examined if

- steers of different breeds grazing at different stocking densities are able to adapt their grazing behaviour to structurally heterogeneous and biodiverse swards;
- low stocking densities lead to increased selectivity of grazing steers and, therefore, to better animal-related performance;
- steers of the traditional breed German Angus are better adapted to a system maintaining biodiverse grassland than Simmental steers, possibly due to differences in grazing behaviour, selectivity and performance parameters.

Furthermore, their bite selecting behaviour and their feeding preferences in relation to availability and changes of forage on offer in terms of quantity and quality should be studied. This way, it should be possible to get a deeper insight into the animal-sward complex and to draw conclusions for the management of temperate grassland for biodiversity benefits. Differences between breeds or grazing pressures could provide hints for the development of management systems for maintaining biodiverse grassland. By investigating the management and performance of steers grazing heterogeneous grassland as permanent pasture, insights for the establishment of production systems utilising biodiverse grassland should be gained. Thus, this study should help to develop management systems providing both efficient agricultural production and biodiversity maintenance or enhancement.

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2. Foraging behaviour of steers grazing a heterogeneous sward – Effects of breed and stocking density

2.1 Abstract

To prevent temperate semi-natural grasslands, which form an important biodiversity and landscape resource, from further decline, systems allowing both biodiversity maintenance and agricultural production need to be found. Since large parts of semi-natural grasslands were developed through grazing, it might be a management form in line with these goals. The development of grazing systems for biodiverse grasslands requires understanding the grazing behaviour of animals foraging on a heterogeneous sward. To get a deeper insight in the interrelation between the grazing animal and a heterogeneous sward, this three-year study investigated the effect of stocking rate and breed of steers on foraging behaviour in heterogeneous grassland.

A heterogeneous, moderately species rich grassland was used as permanent pasture for yearling steers. Three treatments were established: At **m**oderate stocking, steers of the **c**ommercial breed Simmental were used to maintain a compressed sward height (CSH) of 6 cm (treatment **MC**). At **l**enient stocking, steers of the **c**ommercial breed Simmental (treatment **LC**) and of the **t**raditional breed German Angus (treatment **LT**) were used to keep CSH at a level of 12 cm. The objective of MC was to maximise agronomic output, while in LC and LT, biodiversity should be increased. On three occasions during the grazing season (three periods), the behaviour patterns 'grazing', 'walking' and 'ruminating' were observed during four daylight quarters (DLQ). In addition, bite and step rate were estimated.

The animals used about half of the observation time for the behaviour pattern 'grazing'. Animals of treatment LT spent slightly less time of the day grazing than MC- and LC-steers (51, 51 and 46 % for MC, LC and LT, respectively). The steers of the traditional breed spent significantly less time per day 'walking' (5, 5 and 3 % for MC, LC and LT) but needed more time for 'ruminating' (17, 19 and 22 % for MC, LC and LT). Steers took 61.2, 58.0 and 55.0 bites per minute and 7.9, 8.2 and 8.2 steps per minute in treatments MC, LC and LT, respectively. Different stocking densities had no effect on steer behaviour per day, but caused behavioural

differences in the different DLQs. Grazing behaviour was mainly influenced by diurnal and seasonal patterns, furthermore by breed of steers. Variations in climate led to differences between the years.
Grazing extensively managed, heterogeneous grassland with steers of a beef cattle breed at lenient stocking did not seem to have had negative effects on animal behaviour.

2.2 Introduction

Temperate semi-natural and mesotrophic grasslands are an important biodiversity and landscape resource (Pärtel *et al.* 2005). However, the proportion of such valuable grasslands decreased in the European Union (EU) during the last 50 years (Rook *et al.* 2004). Economic pressures led to abandonment of less productive agricultural land and to intensification of productive grassland (Isselstein *et al.* 2005). Less productive, possibly biodiverse grassland might be used by beef cattle or sheep. But the number of cattle and sheep, which are the main agriculturally important grazer species, also declined in the EU during the last decade (EUROSTAT 1992 - 2002). This could lead to a lack of animals able to maintain biodiverse grassland that is in danger to be abandoned. To prevent a further reduction of biodiverse grassland area and of the number of animals able to maintain it through grazing, systems that allow both biodiversity maintenance and agricultural production need to be found (Isselstein *et al.* 2005). Combining maintenance and production, grazing as management system could be used. Grazing already took part in the development of grasslands, especially in areas, where alternative agricultural utilisation was impossible (Spatz 1994). Grazing is the most important process to compound the spatial variability of quantity and quality of herbage on natural grassland (O'Reagain and Schwartz 1995). The grazing animal is able to utilise even areas inaccessible to mechanical maintenance. In contrast to mowing and fertilisation, grazers defoliate selectively and supply nutrients irregularly (Spatz 1994). Thus they influence the structural complexity of grasslands, i.e. patch type, scale and stability (Tallowin *et al.* 2005). In order to assess the role of the grazing animal in developing and maintaining biodiverse and heterogeneous grasslands, it is necessary to understand the factors that influence grazing behaviour. Foraging behaviour of animals grazing different sward types is well studied (Parsons *et al.* 1994, Rook *et al.* 2002, Dumont *et al.* 1995, Rutter *et al.* 1999). It is also well known, that the grazing animal plays an important role in conservation of grasslands. Grazing at low stocking rates nearly always makes the number of plant species increase (Bakker 1989). Herbivores are able to determine the structure of the grazed plant community and possibly system dynamics (WallisDeVries 1998). On a proper density animal grazing is able to enhance plant species richness, but very little is known of the potential of herbivores to create and maintain structurally varying grasslands (Van Wieren and Bakker 1998). To this end it is necessary to explore how animals react to swards that are heterogeneous in structure and quality and offer potentially suboptimal nutrient contents.

This research investigated the grazing behaviour of steers in reaction to heterogeneous grassland. Two cattle breeds and two stocking rates were considered, and the influence of diurnal variations (Arnold and Dudzinski 1978) was assessed by studying daylight quarters (DLQ). It should be examined if there are differences in grazing behaviour when cattle of different breeds graze heterogeneous and biodiverse pastures at different levels of grazing pressure.

2.3 Materials and methods

In spring 2002 a three-year study was established within the framework of the EU-project FORBIOBEN (Rook *et al.* 2004) on a permanent pasture at the experimental farm Relliehausen of Göttingen University, in the Solling uplands 40 km Northwest of Göttingen, Germany (51°N 9°E, 180-230m AMSL). The long-time precipitation average of this site amounts to 879 mm, the mean temperature is 8.2°C. The grassland was visually assessed as a Lolio-Cynosuretum and moderately species rich (~11 species/m^2) (Sahin 2005). During the preceding 10 years, it had been grazed all year round by a suckler-cow herd. Furthermore the grassland had been managed as a permanent pasture and without any fertiliser application. During the study, neither fertilizing nor maintenance measures of the sward took place. Table 2.1 shows the climatic conditions during the three years of research.

Table 2.1: Monthly mean temperature (mean °C) and total precipitation (sum mm) in the project area (Deutscher Wetterdienst)

	2002		2003		2004	
	mm	°C	mm	°C	mm	°C
April	87.1	7.3	45.8	8.1	48.8	8.6
May	92.8	12.9	42.7	12.9	50.1	10.7
June	86.6	16	45.4	18	60.7	14.5
July	156.7	16.8	41.5	18.3	115.9	15.6
August	73.4	18.5	24.9	20.3	76.3	17.7
September	35.9	12.7	61.6	13.1	57.9	13.2
October	123.4	7.7	97.8	5.4	27.3	9
Values per year	1215.9	9.0	693.2	8.9	871.0	8.4

2.3.1 Treatments and management

Using 12-months-old steers, three grazing treatments were established in triplicate according to a randomised block design with a paddock size of 1.0 ha.

The animals used were bought from different farms after weaning in the preceding autumn. They were of nearly the same age and weight and had some grazing experience. Immediately after their arrival at the experimental farm, they were castrated using the Burdizzo-method (Veterinary Science Group OMAFRA 1999). Until being brought to pasture in spring, they were fed medium quality round bale silage and did not get any concentrates.

At **m**oderate stocking, steers of the **c**ommercial breed Simmental were used to maintain a compressed sward height (CSH) of 6 cm (treatment **MC**). The purpose of this treatment was to maximise the agronomic output. At **l**enient stocking steers of the **c**ommercial breed Simmental were used to keep the CSH at a level of 12 cm (treatment **LC**). The objective of this treatment was to increase biodiversity. For the third treatment, also at **l**enient stocking, steers of the **t**raditional breed German Angus grazed the pasture. Like LC, this treatment (treatment **LT**) had a target CSH of 12 cm and was supposed to enhance biodiversity.

During the three years, paddocks were grazed continuously from April/May to September/October. Weekly measurements of CSH were carried out with a disc-meter (Castle 1976), and the stocking density was adjusted by a put-and-take-system to meet the target CSH. Due to a draught in the summer of 2003 (see Table 2.1), animals had to be removed from the paddocks for about three months from end of June to the end of September. CSH, steers' weights and stocking density at the times of animal observations are shown in Table 2.2.

Table 2.2: Compressed sward height, live weight and stocking density during the 3 year project (means and standard deviation)

		2002			2003		2004		
		Spring	Early summer	Late summer	Spring	Late summer	Spring	Early summer	Late summer
		Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
CSH (cm)	MC	12.3	8.3	6.5	8.5	7.1	9.2	5.8	5.5
		(3.9)	(1.0)	(0.5)	(0.3)	(0.4)	(0.1)	(0.3)	(0.5)
	LC	18.5	10.9	8.4	12.9	8.0	20.6	10.4	7.0
		(0.3)	(1.9)	(0.3)	(1.9)	(0.5)	(3.2)	(0.5)	(0.8)
	LT	16.2	10.9	9.3	11.7	8.3	19.8	10.8	8.1
		(2.5)	(1.5)	(1.1)	(0.2)	(0.8)	(1.9)	(0.9)	(1.1)
Live weight (kg / animal)	MC	284	331	346	330	402	343	379	370
		(10.9)	(16.8)	(16.5)	(29.6)	(33.0)	(34.52)	(38.0)	(57.6)
	LC	293	351	381	320	404	369	437	439
		(13.9)	(19.3)	(19.3)	(21.0)	(31.8)	(8.4)	(22.5)	(13.8)
	LT	372	429	459	327	403	359	422	441
		(10.0)	(11.1)	(14.1)	(18.3)	(19.9)	(38.9)	(49.7)	(27.6)
Stocking density (animals / ha)	MC	6.0	6.0	5.7	6.3	4.3	6.3	4.7	4.3
		(<0.1)	(2.0)	(0.6)	(0.6)	(0.6)	(2.1)	(0.6)	(0.6)
	LC	3.0	4.0	3.3	3.0	3.0	3.0	3.0	3.0
		(<0.1)	(<0.1)	(0.6)	(<0.1)	(<0.1)	(<0.1)	(<0.1)	(<0.1)
	LT	3.0	3.7	3.3	4.0	3.0	3.0	3.0	3.0
		(<0.1)	(0.6)	(0.6)	(<0.1)	(<0.1)	(<0.1)	(<0.1)	(<0.1)

2.3.2 Behaviour Observation

Following Dumont *et al.* (2004), behaviour observations were carried out on three occasions throughout each grazing season: in spring (May/June), i.e. before the flowering of major sward components, in early summer (July) with the sward heterogeneity being expected to be at maximum and in late summer (September/October), when cumulative treatment effects were expected to be at maximum. The behaviour of three core animals within each paddock was recorded