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Impact of pasture sward height on nutritive values in the Alpine region.

Influence de la hauteur d'entrée au pâturage sur la valeur nutritive de l'herbe dans les Alpes.

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INTRODUCTION: Dairy farming in the Austrian Alps

In a context of fierce competition of agricultural products on the global market and an increased volatility of milk prices, cattle farmers find it harder and harder to be sustainable. A common way to enhance competitiveness is to increase farms' and herds' sizes while relying more and more on the combination of highly productive dairy types and high energy content concentrate feeds. This tendency can be observed in important dairy producing countries such as the Netherlands or the UK where the average herd size is between 50 and 100 heads (Eurostat, 2005). Austrian dairy farming, at least in lowland, has followed the same trend since the 1970s, namely, change from traditional, small scale, forage based farms, towards large and specialised structures with high concentrates supplementation. But small farm structures still remain, especially in dairy production. In fact, 70% of Austrian dairy farms – producing 65% of the national milk – are in the Alpine region (Buchgraber *et al.,* 2011) where large structures are rare. Only 1.6% of Austrian grassland fields are larger than 5 hectares and the largest mowed meadow has an area of 33 hectares (Buchgraber *et al.,* 2011) with an average herd size in specialised dairy farms of 19 LU. The environmental (altitude, low temperatures, short vegetation period, low net primary productivity, slope, soils) and economical handicaps in those regions (limited agricultural and business sectors, long distances, lack of infrastructure and agricultural services) hardly allow any production but low-input, small-scale grassland farming (Schaumberger, 2010; Hopkins, 2011; Thomet *et al.,* 2011). Grassland accounts for nearly 60% of total farmland in Austria of which 92% are permanent grassland (BMLFUW, 2005).

These particular conditions explain why mountainous agriculture is generally considered by economists and sociologists as a declining sector (Fleury *et al.,* 2004). Between 1980 and 2000, countries like Slovenia, Italy and France have shown rates of farm abandonment approaching 50% in the Alps (Streifeneder, 2009, cited in Steinwidder *et al.,* 2011). In Austrian Alps the process has been five times slower (BMLFUW, 2010) thanks to direct subsidies and site-specific management that allow Alpine farmers to mitigate their high production costs (Lobsiger *et al.,* 2010).

But the process of improving competitiveness and sustainability should always continue and the present work falls into this effort of finding the best dairy system to fit mountainous regions of the Alps. Implementing a grass-based system being the long-term objective, the experiment described in this work looked at different pre-grazing sward heights and their effect on forage quantity (productivity) and quality (sward structure, botanical composition, nutritional values), over one vegetation period.

To begin with, a part dealing with the benefits of grass in dairy production and with grassland research will synthesizes the literature available on the theme and provide a quick overview of the main issues and reasons why this work had been undertaken in the first place. The objectives of the present trial will end this theoretical chapter to move on to the actual experiment in a chapter material and methods. The results and the discussion will be addressed together in the last chapter.

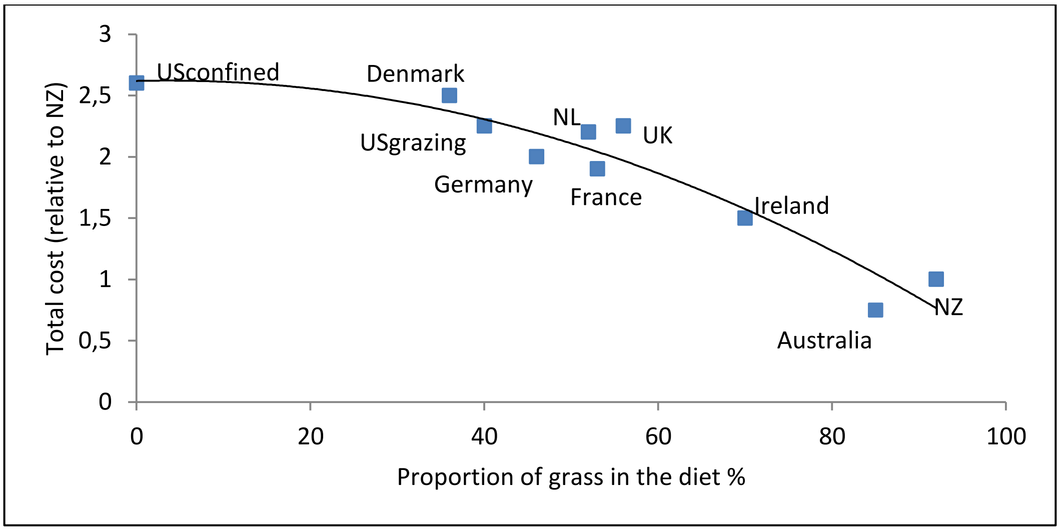
Part 1: Context and objectives of the trial

I. Grass-based dairy production: the key to sustainability

A. Grass is the cheapest feed in a low-input context

Feed costs account for approximately 80% of total variable costs of milk production (Shalloo *et al.,* 2004, cited in Coleman *et al.* 2010). In a context of great volatility of market prices and increased energy prices, the model based on intensification and the reduction of grazing does not seem to be the best scenario (Peyraud *et al.,* 2010). On the other hand, dairy systems trying to maximize the utilization of grass have been shown to be very competitive (Fig 1). Under average production costs, unprocessed and freshly cut and fed feeds are indeed the least expensive (Zimmermann, 2006, cited in Thomet *et al.,* 2011), partly through reduced transportation and storage. Consequently, the total cost of production is negatively correlated to the proportion of grass in the cows' diet (Fig. 1). One of the main objectives of pasture-based dairy producers is to maximise profitability per hectare of grazing through increased pasture production and utilisation, and reduced concentrate supplementation (Dillon *et al.,* 2008; Steinwidder *et al.,* 2010). This objective is fully achieved in countries such as Australia and New Zealand which benefit from very large grazing areas. The aim of this system is to synchronize the herd's feed requirements, strongly dependant on the stage of the reproductive cycle, with the rate of pasture growth. Ideally, grazed pasture should provide at least 60% and up to 90% of the cows' feed throughout the year. In Europe, event with lower expectations, grass-based dairy production seems attainable. In Ireland for example, grass accounts for nearly 70% of dairy cows' total diet (Dillon *et al.,* 2008). Moreover, Steinwidder *et al.* (2010) suggest that under proper management, a pasture proportion of 45 to 60% is achievable in disadvantaged mountainous conditions as well.

A grazing system shows however difficulties of management. The feed resource is unstable during the season in terms of productivity per area of land and feeding value. There is also an important inter-annual growth curve variability. As a result, animal performances may be variable as well, and this is not adapted to the market today which requires constant supply of goods in quantity and quality. The increased use of automated milking systems also makes grazing more difficult. (Peyraud *et al.,* 2010).



<u>Figure 1:</u> Total costs of milk production related to the proportion of grass in the cows' diet (Dillon *et al.,* 2008)

B. Grass to reconcile economics and environmental aspects

Despite lower milk yield per cow, switching to a low-input system based on pasture, with up to 60% of the diet made up by grass, will generate lower marginal costs and higher production efficiency per unit milk (Steinwidder *et al.,* 2010). According to a study using Life Cycle Assessment to

compare different dairy production systems (Basset-Mens *et al.,* 2009), maize silage is responsible for 40% of total energy use. Low-input farms (no maize silage and no mineral fertiliser) can have up to three times less energy consumption than conventional farms.
The reduction of fertiliser and diesel does not only have economic merit. The benefits for the environment cannot be neglected. Basset-Mens et al. (2009) have shown that global warming potential, eutrophication as well as acidification per both kg of milk produced and hectare of land were lower in the low-input system than in the systems using maize silage and N-fertiliser. On the other side, it is also true that high-roughage diets produce proportionately more methane (Crutzen *et al.,* 1986, cited in Milne, 2005).
Besides, extensively managed grasslands also show a high number of plant species among which a greater proportion of red list species, the highest proportion being found in extensive pastures, with up to 16 red list species per area of land (Pötsch *et al.,* 2005).
But unadapted grazing can have detrimental effects on the environment, on soil structure in particular. Under wet soil conditions, animal treading leads to an increased bulk soil density reducing soil aeration and infiltration, which can limit pasture growth (Dewry *et al.,* 2008, cited in Eriksen *et al.,* 2010). Limited roots development also impacts the nitrogen cycle as there is a negative correlation between root biomass and nitrogen leaching (Minns *et al.,* 2001). Nitrogen leaching from grazed pasture increases exponentially with increased N inputs and urinary-N accounts for 70 to 90% of total N leaching (Ledgard, 2001, cited in Eriksen *et al.,* 2010). The systems based on ley-arable rotations might be more at risk of nitrate leaching than the ones using permanent grasslands, as observed during the Green Dairy project (Raison et al., 2008).

II. High quality products for a better market price

A. Promoting agriculture in disadvantaged regions of the Alps

Contrary to intensive agriculture in lowland, Alpine small-scale farming has managed to keep a good image through the multifunctional roles it plays (Fleury *et al.,* 2004). It helps to maintain an attractive landscape, through a co-operation between farmers and tourism business (Schermer, 2004), as farming is considered as a cultural heritage in these regions. Moreover, environmental issues in the Alps are equally due to both intensification and land abandonment, reforestation in particular (Fleury *et al.,* 2004; Lobsiger *et al.,* 2010) so keeping an extensive grassland management is necessary for the preservation of a healthy landscape.
Species rich plant stands with a high share of herbs contribute to a high aesthetic value when in bloom – which is of importance when we consider the fact that some regions only live from tourism – and are a great food supply for flower-visiting insects (Bohner *et al.,* 2012)..
This is also an animal-friendly system as grass is the original feed for ruminants. Delaby *et al.* (2009) have found that cows receiving concentrate supplementation at pasture had more digestive disorders.
Given the difficult conditions of the Alps, competition on a national or European market as a commodity product is out of the question but the already low-input management of dairy farms allows a relative easy conversion to organic farming. In this context, organic farming and the higher market value secured for those high quality products goods seems to be a good solution to support agriculture in mountains. It is no surprise that already 25% of grasslands in Austria are managed organically in 2009 (Angeringer *et al.,* 2011) and that Austria is the leader in the European Union in terms of organic farming. The organically managed area has reached in 2011 the threshold of 20% of the total UAA while the European average is around 5% (BMFLUW, 2012).
Through this conversion, farmers can enjoy a “premium” market price for the provision of higher quality goods (Hopkins, 2011). This is mainly possible because this type of production meets high consumer recognition in Austria and there is an important market available for organic and locally produced goods (Fleury *et al.,* 2004).

B. Interesting quality and fatty acid composition of milk produced with grass

Many experiments looked into the variations in milk composition according to the diet and particularly into potential nutritional benefits for human consumers of milk produced with grass. Milk produced organically (more fresh grass and less concentrates) showed higher contents of polyunsaturated fatty acids (PUFA) of which n-3 alpha linolenic acid (C18:3 also called ALA),

conjugated linoleic acids (C18:1 and C18:2 also called CLA) and branched fatty acids (Collomb *et al.,* 2008; Butler *et al.,* 2011) when coventional ones had higher contents of monounsaturated (MUFA) and n-6 fatty acids (Collomb *et al.,* 2008). Couvreur *et al.* (2006) have found that the proportion of MUFA and PUFA actually increases linearly with the proportion of fresh grass in the diet, at the expense of saturated fatty acids (SFA). As for the antioxidants content it can be up to 2.5-fold higher in organic milk compared with conventional milk (Butler *et al.,* 2011).
Dairy products such as butter or cheese keep some of the nutritional qualities observed in milk. The proportion of CLA in particular, is not impacted by processing (Butler *et al.,* 2011). But there are also interesting organoleptic changes when feeding more grass to the cows. A decrease in butter hardness by up to 30% (despite the same crystallisation temperature) has been observed, as well as a decrease in the rancid flavour (Couvreur *et al.,* 2006) and a more intense creamy aroma (Butler *et al.,* 2011).
These differences can be explained by the composition in fatty acids of green feed, naturally richer in PUFA but also by the changes in ruminal activity (Collomb *et al.,* 2008). 30 to 60 % of grass in the diet is enough to notice an improvement in both nutritional and sensorial properties of butter (Couvreur *et al.,* 2006).

III. Optimisation of pasture utilisation in a grass based system

A. Two types of grazing system: rotational and continuous grazing

1. Continuous grazing or set-stocking

The animals have access to the whole grazing area day after day during the entire grazing period. This system, in its purest form, only exists in very extensive grazing areas where the land available is large and the stocking rates are low relative to pasture production. In intensively managed areas, ‘standard’ continuous grazing has been slightly modified to suit higher stocking rates and to balance grass supply and requirements. Alternative continuous grazing system can be implemented through the use of a ‘buffer area’, progressively made available to the cows if necessary (Mayne *et al.,* 2000).

2. Rotational grazing

The grazing area is divided into a number of small paddocks and the cows are allowed to feed on one paddock for a short period (e.g. one day). In this system the sward is grazed at regular intervals following a longer period of regrowth. There are different types of rotational grazing systems, with more or less flexibility (integration of grazing and hay/silage conservation, adjustment of the grazed area through the use of movable electric fencing). The length of the rotation cycle may vary, with the minimum recommended length being 18 days in early season and up to 50-70 days in late automn, in lowland pastures (Mayne *et al.,* 2000).

3. Comparison of both systems in a grass based scenario

Both systems give good results in mountainous conditions in terms of yields as well as forage quality. According to Pulido *et al.,* (2003), the continuous grazing system is more adapted to high sward heights, whereas the rotational system gives similar results with both high and low heights. But Starz *et al.* have concluded that the results (energy, crude protein and neutral detergent fibre contents) obtained with containous grazing on shord swards (10-12 cm) were perfectly sufficient for mountainous conditions (Starz *et al.,* 2011) which proves this system to be suitable for small scale farming in the Alps. In a rotational system, Pavlu *et al.* (2006) have shown that when intensively grazed (post-grazing height 5 cm), the pasture gave a better forage yield and a better organic matter digestibility than when extensively grazed (post-grazing height 10 cm). But extensive grazing promotes selective patch grazing which is in favour of a higher biodiversity within the sward (Adler *et al.,* 2001, cited in Pavlu *et al.,* 2006). Mean estimated herbage and total dry matter intake, grazing time, and ruminating time were significantly greater on the continuous grazing system (Pulido *et al.,* 2003), which is relevant to a grass-based system where stocking rates are higher than in conventionnal concentrates-based systems.

Rotational systems offer greater reactivity in case of grass surplus or shortage and they provide to the cattle a herbage in an 'optimum' form for prehension (i.e. tall, dense swards) (Mayne *et al.,* 2000).

B. Farm profitability is linked to productivity per hectare

1. Grassland productivity in dairy producing regions of Europe

In Ireland, intensively managed pastures produce 11.5 (Wims *et al.,* 2010) to 15.8 t ha^{-1} (McEvoy *et al.*, 2010). In Switzerland, pastures exceeding 12 t ha^{-1}year^{-1} are considered the most productive (Mosimann *et al.,* 2010). In the Eastern part of the Alps, where the climatic conditions are more favourable, it is possible to get an annual yield of 9.0 to 11.0 t ha^{-1} in respectively grazed or cut organically managed pastures (Starz *et al.,* 2010). An average daily grass growth of 75 kg ha^{-1} has been recorded by Mosimann *et al.* (2010) in Switzerland.

2. Increasing stocking rates/decreasing herbage allowance

As stocking rate increases, milk production per cow decreases but milk production per hectare increases by up to 20% (MacCarthy *et al.,* 2011). In grass-based systems, farm profitability is thus more closely related to milk production per hectare than milk production per cow (Holmes *et al.,* 2002). Lactations are also shorter to make the best of the grazing season. The reduction of herbage allowance is compensated by a better utilisation of pastures through less refused areas (less wastage), improved herbage growth and increased energy efficiency associated with reduced body weight. An increase in stocking rate of 1 cow/ha results in the reduction of 1 kg daily herbage allowance per cow only (MacCarthy *et al.,* 2011). If pre-grazing herbage mass is low (< 2000 kg DM ha^{-1}) there is a risk of incomplete growth of the grass, the daily intake will be restricted because of small bites. If it is too high (> 3000 kg DM ha^{-1}), some of the leaves will be aging, associated with reduced digestibility (40% in average while it is about 75-80% in young leaved-swards). Also post-grazing yield will still be high which will be resulting in wastage (Holmes *et al.,* 2002).
Roca-Fernández *et al.* (2010) suggest that it is possible to achieve high herbage utilization with a pre-grazing herbage mass of 1600 kg ha^{-1} and a daily allowance of 15 kg cow^{-1}. This management should lead to improved sward quality through increased leaf/stem ratio and lower proportion of dead material.

C. Botanical composition and its impact on pasture productivity and quality

1. Botanical composition in intensively managed grasslands in the Alps

a) High diversity of plant species…

In Alpine grasslands, the botanical composition is extremely complex, with the highest diversity – up to 115 plant species – observed in alpine meadows (Pötsch *et al.,* 2005). In intensively managed permanent grasslands, swards still contain between 20 and 30 different species of vascular plants per area (Bohner, 2007). Among them many different types of grasses and a non neglectable proportion of herbs are to be found (Angeringer *et al.,* 2011).
Species diversity depends strongly on the type of land use, characterized by different intensity levels. In the Alps, 40% of the grassland areas have a slope greater than 25% from which arise problems for harvesting, fertilizing and re-sowing. Due to these restrictions, those areas can only be managed extensively (low number of animals, low fertilizing intensity), whence the positive correlation between altitude of grassland and species diversity (Pötsch *et al.,* 2005).

b) …which is sensitive to management

In Austria, the incidence of pastures and meadows is only the result of agriculture (Bohner, 2007).
Intensification leads to a decrease in plant diversity, a loss of red list species, a uniformisation of plant communities, and a change in species composition (Bohner, 2007). Too high cutting frequency leads to the loosening of the swards and appearance of gaps, which allow the development of plant stands adapted to nutrient-rich soils such as *Rumex spp, Taraxacum officinale,* and *Poa trivialis,* with low feeding value (Bohner, 2007; Pötsch *et al.,* 2010; Bassler et al., 2011). A similar correlation is observed in terms of stocking rates. The highest floristic diversity has been observed between stocking rates of 0.5 and 1.5 LU ha^{-1} of grassland, suggesting that a minimum grazing contributes to maintaining a high floristic diversity as opposed to no grazing at all

(Pötsch *et al.,* 2005). Moreover, nutrient-poor soils are more resistant to vegetation changes resulting from abandonment than nutrient-rich ones (Bohner *et al.,* 2012).

2. Higher yields and better yield stability with association of species…

In a pan-experiment carried out in 17 countries in Europe, it has been shown that grass-clover associations containing four species had higher yields than the same species sown in monoculture, and that whichever the proportion of each species. There was even a transgressive over-yielding, that is, the yield of the mixture was better than the one of the best monoculture (Kirwan *et al.,* 2007, cited in Peyraud *et al.,* 2010). The more species are to be found, the more resilient to disturbance is the grassland. When comparing simple grass-legume associations to mixtures containing up to 9 species, we can see that complex sward mixtures, have a better yield stability in case of dry year and a reduced weed pressure (Sanderson *et al.,* 2005). For a given number of species, plant communities with less functional groups are less productive and the loss of one functional group reduces productivity (Minns *et al.,* 2001). Minns *et al.* have found moreover that nitrogen retention is better in mixtures of 8 or more species. This improved ability to withstand environmental variations is a key feature in a low-input system.

Sanderson *et al.* (2005) observed however that, in complex swards, species composition is not stable on the long term.

3. …but quality might vary

When comparing equally managed ryegrass-clover (*Lolium perenne*, *Trifolium repens*) and Winterhardy (*Festuca pratensi, Phleum pratensis, Poa pratensis, Trifoium repens*) pastures, the differences observed in terms of quality between pastures were smaller than the ones observed between cuts/months (Johansen, 2010). Pastures subjected to unfavourable conditions often contain a lot of nitrates (non-protein nitrogen component) which are of low nutritive value (Beever *et al.,* 2000). Swards with high species diversity being more resilient to disturbance (Sanderson *et al.,* 2005) and subjected to a lower 'age effect' (Peyraud *et al.,* 2010), the quality of forage can be stabilized over the vegetation period.

Mixed pastures with at least 25% clover have showed to have higher crude protein content and lower fibre content than fertilized pure ryegrass pastures (Harris *et al.,* 1997; Ribeiro *et al.,* 2005; Soder *et al.*, 2005). In terms of energy content, Bohner observed a negative correlation between plant species richness and energy content of forages (Bohner, 2007). It is interesting to note moreover that complex swards used in Switzerland and Austria make it difficult to use the pasture at its best state because the period of optimal growth is staggered from one species to another (Eastes *et al.,* 2009). In particular, flowering period, which is a period of low quality forage, takes place over a wider period.

D. Voluntary intake is also of importance

High forage quality and yield are necessary but not sufficient to ensure that the cattle's feed requirements are met through appropriate grassland management. Voluntary intake of forage must also be properly determined as it is quite variable from one animal to another. Dry matter intake for dairy cows is usually between 15.2 and 23.9 g kg^{-1} live-weight according to their level of production and live weight (Pozdisek *et al.,* 2010).

Daily herbage intake has been defined by Rook (2000) as the result of several factors, depending both on animal grazing behaviour and swards' structure:

Daily intake = instantaneous intake x grazing time

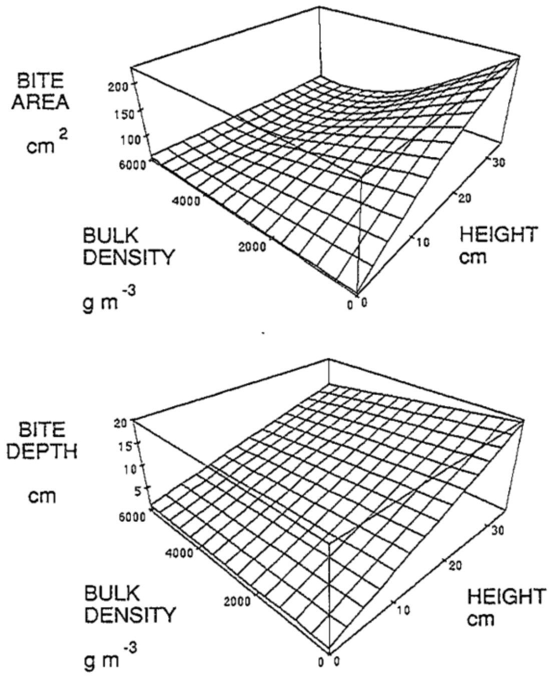
= [bite mass x bite rate] x [meal duration x number of meals]

1. Bite mass or bite weight

Bite mass is influenced by bite depth and bite area, which are themselves functions of sward height and sward bulk density (herbage weight per unit canopy volume, hereafter referred to as density). Bite mass is greatest on tall-dense and short-dense swards and smallest on short-sparse ones (Distel *et al.,* 1995; Prache & Peyraud, 1997). But Laca *et al.* (1992) observed heavier bites on tall sparse grasses than on short dense ones (Fig. 2) which suggests that bite mass is more sensitive to height than to density. Normal density for grass sward ranges from 571 to 2,969 g m^{-3}. In very dense swards, the gain in bite depth due to increasing sward height is almost counterbalanced by the reduction in bite area (Laca *et al.,* 1992). For grasses, density is higher in the parts close to the ground whereas for legumes there is a bottom-up increase in density (Laca *et al.,* 1992). Therefore, bite mass can be greater for legumes than for grass swards despite a shallower bite depth.

2. Bite rate

Bite rate or intake rate is the amount of herbage mass ingested per unit time. It results from momentary interactions between sward structure and ingestive behavior. Indeed, cattle seem to select patches in a manner consistent with maximization of intake rate (Distel *et al.,* 1995; Prache & Peyraud, 1997). With 18 cm high swards, intake rate ranges from 3.5 to 4 kg DM $hour^{-1}$ and it decreases with height. In much shorter grass however, high density compensates for the height drop (Mayne *et al.,* 1997, cited in Rook, 2000). Chewing time increases with increasing bite mass as total chews per bite increases. Therefore biting rate decreases when density increases (Rook, 2000).



<u>Figure 2:</u> Fitted surface response for bite area and bite depth as functions of sward height and sward density (Laca *et al.,* 1992)

3. Factors influencing grazing time: the stage of growth of the plants

There is a tendency for increased voluntary intake with decreasing crude fibre content and increasing crude protein and net energy lactation (Pozdisek *et al.,* 2010). Yet, crude fibre content increases over the vegetation period and crude protein content generally decreases, as well as net energy lactation (Gruber et al., 2011). This phenomenon is known as ‘age-effect’.

In Alpine pastures, crude protein ranges from 117 g kg DM^{-1} (Gruber *et al.,* 2011) to 236 g kg DM^{-1} (Starz *et al.,* 2011); crude fibre from 176 g kg DM^{-1} (Starz *et al.,* 2011) to 333 g kg^{-1}DM (Gruber *et al.,* 2011); and net energy lactation from 4.78 MJ NEL kg DM^{-1} (Gruber *et al.,* 2011) to 7.03 MJ NEL kg DM^{-1} (Starz *et al.,* 2011). The differences between these results can be explained at least partly by the botanical composition.

IV. Objectives of the present trial

Contrary to ryegrass-dominated lowland pastures, Alpine grassland shows a high plant biodiversity even in intensively managed areas. This typical botanical composition influences the nutritive value of the forages and the structure of the swards, due partly to a high proportion of herbs. The proportion of herbs, grasses and legumes, and the share of each species are not constant over the vegetation period and neither is forage quality.
It has already been shown that management strategies influence DM yield and botanical composition. The aim of this trial was to measure the characteristics of short grazed swards and the changes over the vegetation period. A further aim was to identify for a grass-based dairy production system the optimal pre-grazing height on a paddock, in terms of structure of the sward, energy and nutrient contents. Optimal pre-grazing height in France and Switzerland varies between 10 and 22 cm from one author to another (Eastes *et al.,* 2009) but the present work focuses on short swards between 8 and 15 cm.
The results of this trial should contribute to implement an efficient grass-based dairy production system in small scale farms in the Alps.

Part 2: Material and methods

- Site characteristics

The trial was conducted from the 8th of April to October 2013 (experiment still in progress at the time of this report) on each of two similar, organically managed permanent pastures, only differing slightly in botanical composition: latitude 47° 31’ 03’’ N, longitude: 14° 04’ 26’’ E, 680 m altitude. Both pastures will be hereafter called by their names: Beifeld and Stallfeld. The climate is continental with a mean annual air temperature of 7°C and a mean annual precipitation of 1014mm, of which 600mm fall during the vegetation period of 200 days (Tab. 1). On average in the region, the growing season lasts from the end of March to the beginning of November.

Table 1: Climate data for the research farm from the nearest air monitoring station (ZAMG, 2001)

		Irdning (data from 1971-2000)
Mean annual air temperature		7°C
Mean monthly air temperature	**July**	16.5°C
	January	-3.1°C
Days ≥ 25°C		44
Days ≤ 0°C		132
Days with snow cover ≥ 1cm		98

Both pastures are hillside facing south with an average slope of 18% (Digitaler Atlas Steiermark, 2013). The management is rather intensive for this region, with 3 to 4 cuts per year and a rate of fertilisation of 130 kg N ha^{-1}.

- Experimental design

To evaluate the effect of pre-grazing height, a complete randomized experimental design with three different target heights (8 cm, 11 cm and 15 cm) and four replications was implemented (Fig. 3). Each paddock consisted therefore of 12 equal squares, that is 24 areas in total. The trial was reproduced, changing each time the place of the cages, over the grazing period as many times as allowed by the rate of grass growth rate.

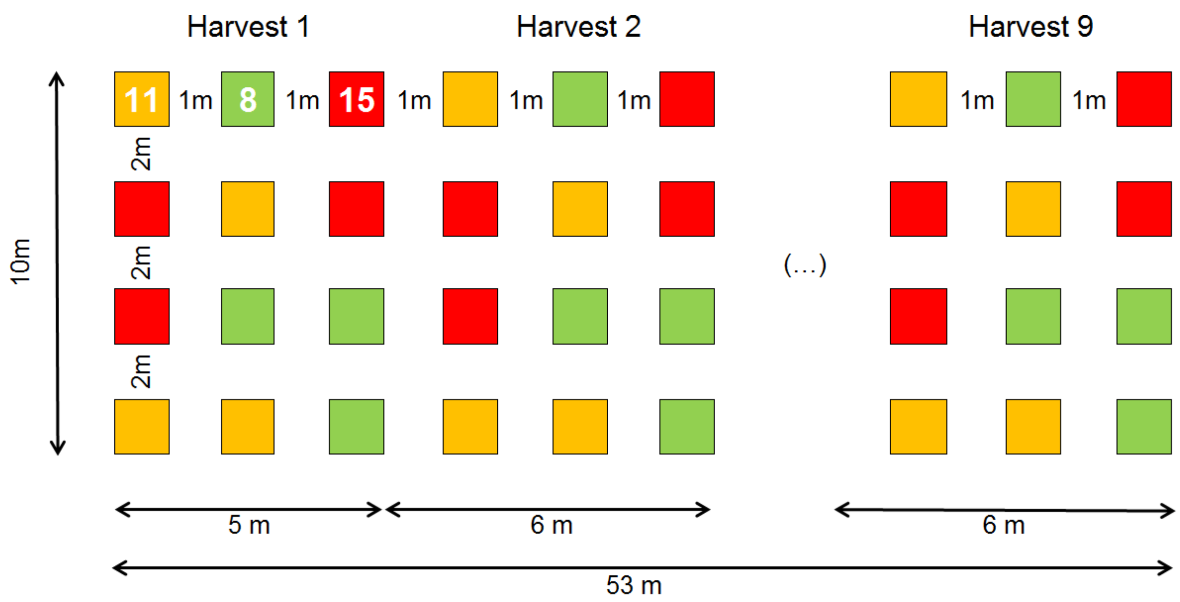


Figure 3: Diagram of the randomised block design used on one of the two experimental areas

Grazing cages have been used to avoid grazing by the dairy cows inside the experimental area (Fig. 4). The cages had a base area of $1m^2$ and were made of mesh-wire (Fig. 5).

Figure. 4: Twelve cages in a complete randomised experimental design (Photo: L. VARGA)

Figure 5: Aspect of the area before harvest (Photo: L. VARGA)

- Botanical composition

The composition of the squares between grasses, legumes and herbs, and the share of each species was assessed before harvest using area percent rating. This means that the share of each species was expressed in percentage of the total area of 1 m² being 100%.

- Harvesting and data collection

Before harvesting, leaf area index (ratio of leaf area to ground area) calculated after the photosynthetically active radiation by AccuPAR LP-80, was determined. LAI is an expression of sward density and therefore gives precious information on productivity. Forage was harvested with an electrical hand mower when reaching the target height. The post-cutting height was approximately 3 cm. The heights before and after harvest were measured using a rising plate meter (Fig. 6). The same method had to be used all over the experiment. After harvest, the cages were transferred to the next areas, mowed down to 2-3 cm.
The fresh matter yield of each area was measured by weighing the total amount of biomass; this procedure was carried out *in situ* to prevent weight loss. Each sample was then subsampled (approximately 0.5-0.6 kg). A further subsample of 0.1-0.2 kg fresh weight of the herbage sample was dried for 48 hours at 105°C for dry matter yield determination. Based on the above measurements, it was possible to calculate herbage mass per centimetre, that is to say density (expressed in kg $ha^{-1}cm^{-1}$):
Density = DM yield per hectare ÷ (precutting height − postcutting height).

- Chemical analysis

The remaining forage was dried at 35°C as long as necessary to allow conservation in anticipation for chemical analysis of the main nutrients and minerals contents via proximate analysis (acide detergent fibre, neutral detergent fibre, crude protein, and organic matter digestibility).

- Statistical analysis of the data

All statistical analyses were carried out using the software SAS 9.2. The data were checked for adherence to the normal distribution using and homoscedasticity using analysis of variance and visual testing of the fit diagnostics. The model used was a mixed model (PROC mixed in SAS 9.2) with a *P*-value of 0.05 (n=72). The fixed effects were the variant (8, 11, 15), the field (two fields) and the harvest (three times), while the columns of the experimental design were used as random effect. The results were displayed as least squares means. The pairwise differences were obtained using the Tukey-Kramer test.

<u>Figure 6:</u> Illustration of the experimental procedure.
Top-left: aspect of the sward before harvest; top-right: evaluation of the LAI; bottom-left and -centre: the rising plate meter; bottom-right: harvesting (Photo: L. VARGA)

Part 3: Results and discussion

I. Results

A. Climate and weather conditions

The vegetation period started on the 8th of April, which is late compared to the previous years (Fig. 7), and the climatic conditions were atypical. There were snowfalls recorded in late March and early April and the average temperature in March did not reach 2°C (Tab. 2). May and June showed very heavy precipitations, over 100 mm per month (Tab. 2).

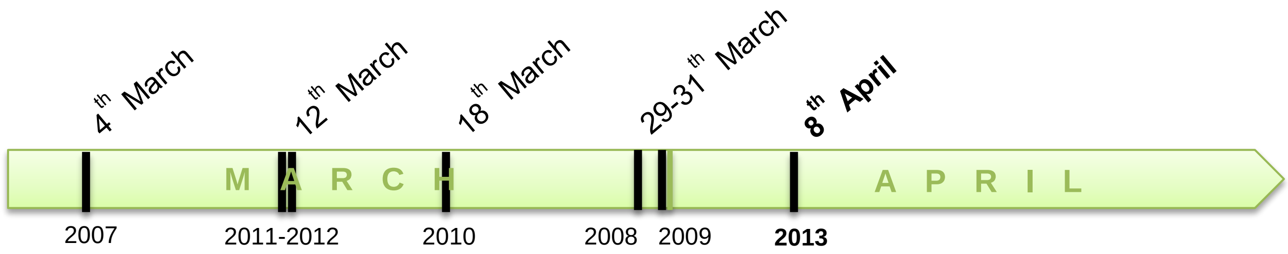


Figure 7: Dates of approximate start of the growing season since 2007 in the experimental area (calculated after on site daily temperatures)

Table 2: Temperature and precipitation data from the 15th of March and for the experimental period

	15.03 – 31.03	April	May	June	July	August
Rainfalls (mm)	32 + 16 (snow)	38 + 5 (snow)	111	155	-	-
Temperatures (°C)	1.7	9.3	12.1	15.6	-	-

B. Botanical composition

1. Inventory of the species present

A total of 30 vascular plant species have been recorded in the experimental areas during the trial (Tab. 3). Among the grass species, English ryegrass (*Lolium perenne*) and Kentucky Bluegrass (*Poa pratensis*), two important pasture and forage plants, had the highest coverage, followed by *Poa supina* and *Agrostis stolonifera* (Tab. 4). White clover (*Trifolium repens*) was the only species of legumes.

The swards contained several species typical of intensively managed grazed grasslands, such as *Poa supina*, *Plantago major*, *Bellis perennis*, and *Taraxacum officinale* (Bohner, 2007).

Table 3: Summary of the grassland species recorded during the trial

Grass		Legumes	Herbs	
- *Agrostis stolonifera*	- *Deschampsia cespitosa*	*Trifolium repens*	- *Plantago major*	- *Ranunculus acris*
- *Lolium perenne*	- *Poa pratensis*		- *Alchemilla vulgaris*	- *Rumex obtusifolius*
- *Poa trivialis*	- *Festuca pratensis*		- *Veronica chamaedrys*	- *Plantago lanceolata*
- *Cynosurus cristatus*	- *Agrostis capillaris*		- *Bellis perennis*	- *Euphrasia officinalis*
- *Dactylis glomerata*	- *Alopecurus pratensis*		- *Glechoma hederacea*	- *Cerastium arvense*
- *Poa supine*	- *Phleum pratense*		- *Veronica serpyllifolia*	- *Ajuga reptans*
	- *Elymus repens*		- *Ranunculus repens*	- *Potentilla reptans*
			- *Taraxacum officinale*	- *Achillea millefolium*

2. Management strategy influences the share of dominating plant species

a) The effect of cutting height and harvest time on species

The target height had no significant effect on the proportion of grass, legumes or herbs (Tab. 4). Grass species made up around 75% of the sward, legumes 15% and herbs 10% in the three variants. Vegetation time on the other hand had a significant effect of the share of legumes and herbs. The coverage of white clover nearly doubled (reaching 19%) in harvest 2 and 3 at the expense of herbs (Tab. 4). There was also an impact on the proportion of *Poa pratensis,* whose coverage dropped by 7% between harvest 1 and harvest 2.

Table 4: Results for the botanical composition displayed as least squares means (LSM)

	Target height/Variant					Field			
	LSM 8	LSM 11	LSM 15	Std Error	P	LSM Beifeld	LSM Stallfeld	Std Error	P
Grass (%)	75.1^{a}	73.3^{a}	73.5^{a}	1.2	0.501	77.7^{b}	70.3^{a}	0.9	<0.0001
***Lolium perenne* (%)**	25.1^{a}	25.3^{a}	25.8^{a}	1.0	0.886	30.2^{b}	20.7^{a}	0.8	<0.0001
***Poa pratensis* (%)**	21.2^{a}	21.7^{a}	20.0^{a}	1.0	0.505	23.8^{b}	18.1^{a}	0.9	<0.0001
***Poa supina* (%)**	8.4^{a}	8.3^{a}	7.1^{a}	0.6	0.288	11.5^{b}	4.4^{a}	0.5	<0.0001
***Agrostis stolonifera* (%)**	7.2^{b}	5.1^{a}	7.5^{b}	0.6	0.017	2.9^{a}	10.3^{b}	0.5	<0.0001
Legumes (%)	14.4^{a}	18.1^{a}	17.2^{a}	1.3	0.113	15.7^{a}	17.4^{a}	1.0	0.249
Herbs (%)	9.9^{a}	8.5^{a}	9.1^{a}	0.6	0.202	6.3^{a}	12.1^{b}	0.4	<0.0001

$^{a-b}$Least squares means within a row without a common superscript differ significantly (P < 0.05)

	Harvest				
	LSM 1	LSM 2	LSM 3	Std Error	P
Grass (%)	76.0^{a}	73.2^{a}	72.8^{a}	1.2	0.109
***Lolium perenne* (%)**	25.9^{a}	24.5^{a}	25.8^{a}	1.0	0.507
***Poa pratensis* (%)**	25.8^{b}	19.3^{a}	17.9^{a}	1.0	<0.0001
***Poa supina* (%)**	7.8^{a}	8.0^{a}	8.0^{a}	0.6	0.971
***Agrostis stolonifera* (%)**	6.8^{a}	6.0^{a}	7.1^{a}	1.0	0.372
Legumes (%)	11.3^{a}	19.4^{b}	19.0^{b}	1.3	<0.0001
Herbs (%)	12.3^{b}	7.4^{a}	7.9^{a}	0.5	<0.0001

$^{a-b}$Least squares means within a row without a common superscript differ significantly (P < 0.05)

b) Botanical composition differed between fields

Both fields were quite different in terms of botanical composition. Beifeld had a higher proportion of grass and half as much herbs as Stallfeld, legumes being constant (Tab. 4). The share of each dominating grass species was also significantly different between fields: *Lolium perenne*, *Poa pratensis* and *Poa supina* had a higher coverage in Beifeld while the coverage of *Agrostis stolonifera* was three times higher in Stallfeld.

C. Sward structure and grassland productivity

Despite different botanical compositions, the fields did not show significant differences in terms of sward quality or productivity.

1. Pre-cutting sward height

Pre-cutting heights were significantly different between the variants (Tab. 5a) and close to the target height in each variant. These results show that the experiment has been carried out with care, fulfilling the objectives set in the beginning. The harvest time appeared to influence pre-cutting height as well. In fact a decrease by 2 cm between each harvest could be observed (Tab. 5a). The least squares means for variant-harvest interactions (Tab. 5b) show that the lowest pre-cutting height was achieved in harvest 3. In variant 15, and less notably in variant 11, pre-cutting height decreased significantly in the course of the trial while in variant 8, harvest time has only a little effect on cutting height.

2. Leaf area index (LAI)

The values obtained for the leaf area index range from 2.25 (variant 8, harvest 1) to 5.21 (variant 15, harvest 1) (Tab. 5b). The LAI increased significantly with the variant and therefore with grass height (Tab. 5a). Among the harvests, harvest 1 showed the highest LAI and harvest 2 the lowest.

Table 5a: Results for sward structure and pasture productivity displayed as least squares means (LSM)

	Variant					Harvest				
	LSM 8	LSM 11	LSM 15	Std Error	P	LSM 1	LSM 2	LSM 3	Std Error	P
Sward height (cm)										
Pre-cutting	9.9[a]	11.6[b]	14.2[c]	0.7	<0.0001	14.0[c]	11.8[b]	10.0[a]	0.7	<0.0001
Post-cutting	3.9[a]	4.2[a]	3.9[a]	0.2	0.107	4.1[b]	4.2[b]	3.8[a]	0.2	0.007
Leaf Area Index	2.38[a]	3.03[b]	4.31[c]	0.2	<0.0001	3.54[b]	3.00[a]	3.19[ab]	0.2	0.045
DM yield (kg ha^{-1})	1,613[a]	2,206[b]	2,894[c]	99	<0.0001	2,453[b]	2,087[a]	2,173[ab]	96	0.026
Density (kg ha^{-1}cm^{-1})	277[a]	312[b]	294[ab]	6	0.026	259[a]	277[a]	347[b]	6	<0.0001

[a-d]Least squares means within a row without a common superscript differ significantly (P < 0.05)

Table 5b: Results for variant-harvest interactions displayed as least squares means.

	Variant - Harvest interactions, Least Squares Means					
	8 - 1	8 - 2	8 - 3	11 - 1	11 - 2	11 - 3
Sward height (cm)						
Pre-cutting	9.0[a]	11.6[ab]	9.1[a]	13.0[b]	11.2[ab]	10.7[ab]
Post-cutting	3.7[ab]	4.3[b]	3.8[ab]	4.2[b]	4.1[b]	4.2[b]
Leaf Area Index	2.25[a]	2.34[ab]	2.56[ab]	3.16[ab]	2.40[ab]	3.51[bc]
DM yield (kg ha^{-1})	1,489[a]	1,715[ab]	1,633[ab]	2,288[bc]	2,011[abc]	2,320[bc]
Density (kg ha^{-1}cm^{-1})	279[abc]	238[ab]	314[cd]	271[abc]	300[bcd]	364[d]

[a-d]Least squares means within a row without a common superscript differ significantly (P < 0.05)

	Variant – Harvest interactions				
	Least Squares Means 15 -1	15 - 2	15 - 3	Std Error	P
Sward height (cm)					
Pre-cut	19.9[c]	12.5[b]	10.3[a]	1.2	<0.0001
Post-cut	4.5[b]	4.0[ab]	3.3[a]	0.3	0.002
Leaf Area Index	5.21[d]	4.22[cd]	3.48[abc]	0.3	0.0004
DM yield (kg ha^{-1})	3,581[d]	2,534[c]	2,567[c]	169	0.002
Density (kg ha^{-1}cm^{-1})	227[a]	292[abcd]	364[d]	9	0.004

[a-d]Least squares means within a row without a common superscript differ significantly (P < 0.05)

3. Pasture productivity

a) Dry matter yield

Dry matter yield per harvest ranges from 1,489 kg ha^{-1} (variant 8, harvest 1) to 3,581 kg ha^{-1} (variant 15, harvest 1) (Tab. 5b). The behaviour of the dry matter yield was similar to the one of LAI, namely, a significant increase with sward height: 600 kg ha^{-1} gained between each variant, and a decrease between harvest 1 and harvest 2 (Tab. 5a). Harvest 3 was intermediate.
When analysing the productivity over the whole period (8th of April until the 24th of July), five harvests have been used to calculate the total dry matter yield and the average grass growth rate, with the following distribution: variant 8 = 5 harvests; variant 11 = 4 harvests; variant 15 = 3 harvests. The total dry matter yield on the whole period of study: 8th of April to 24th of July, is shown in Tab. 6. The lowest and the highest variants differed significantly, with 7,041 kg ha^{-1} and 8,699 kg ha^{-1} respectively (a difference of 1658 kg). The total yield obtained in variant 11 was intermediate.

b) Grass growth rate

The daily grass growth ranges from 66 kg ha^{-1} (variant 8) to 81 kg ha^{-1} (variant 15), the lowest and the highest variants differing significantly (Tab. 6). The chart of grass growth rate over the period (Fig. 8) shows the very quick start of the vegetation in the beginning of April, followed by a slow-down. The reduction in growth rate was particularly pronounced in variant 15 as the daily growth was nearly divided by two between April and June. The lowest growth rate was recorded between the end of May and mid-June for all three variants, followed in variant 8 by a marked increase in July.

Table 6: Results of total yield and grass growth rate over the period (8th of April to 24th of July)

	Variant					Field			
	Least Squares Means			Std Error	P	LSM		Std Error	P
	8	11	15			Beifeld	Stallfeld		
Total yield (kg $ha^{-1}year^{-1}$)	7,041[a]	7,862[ab]	8,699[b]	356	0.025	7,777[a]	7,958[a]	279	0.654
Growth rate (kg $ha^{-1}day^{-1}$)	66[a]	73[ab]	81[b]	3		73[a]	74[a]	3	

[a-b]Least squares means within a row without a common superscript differ significantly (P < 0.05)

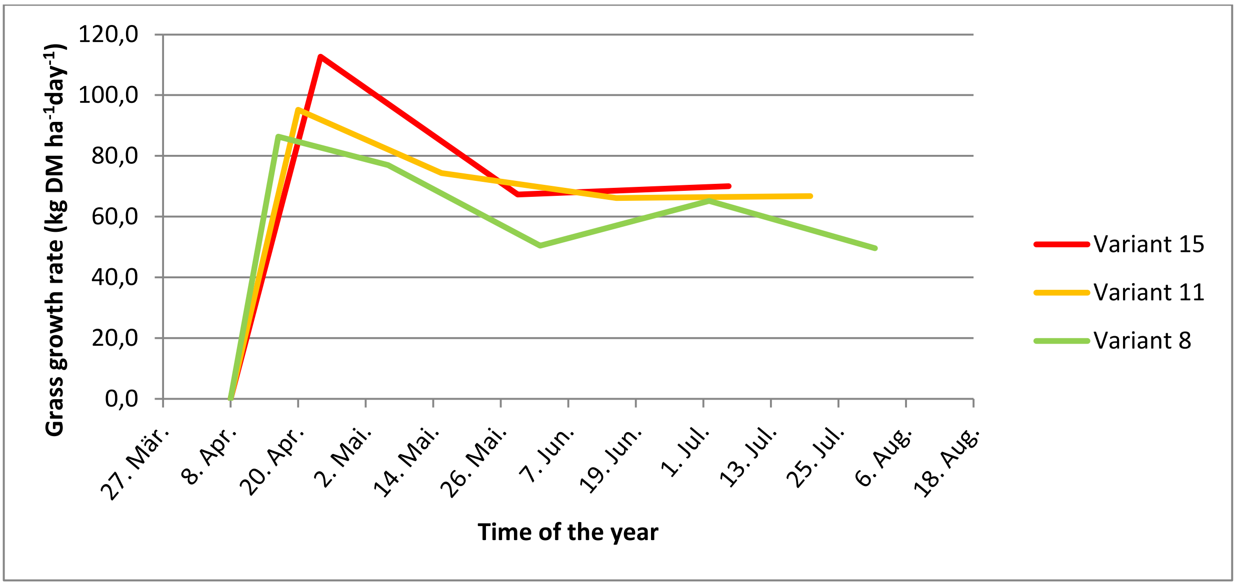


Figure 8: Grass growth rate from the 8th of April for each of the three variants

4. Density of the sward

Sward density varied between 227 kg ha^{-1}cm^{-1}, or 2,270 g m^{-3} (variant 15, harvest 1) and 364 kg ha^{-1} cm^{-1}, or 3,640 g m^{-3} (variant 11, harvest 3 and variant 15, harvest 3) (Tab. 5b). The density of the swards increased significantly with the vegetation period: 88 kg ha^{-1}cm^{-1} gained between harvest 1 and harvest 3 (Tab. 5a). There was also a tendency to an increase from variant 8 to variant 11 and from variant 11 to variant 15.

D. Forage nutritive value: crude nutrients and energy content of the grass

The nutrient and energy contents in dry matter (DM) for harvest 1 are listed in Tab. 7.
Crude ash (CA) content was significantly lower in variant 15 than in the other two. Consequently, the organic matter (OM) content was slightly higher in the last variant.
The highest crude protein (CP) content (235 g kg^{-1} DM) was recorded in the lowest variant and it decreased significantly to the intermediate variant (202 g kg^{-1} DM). Similar to crude protein content, energy expressed as net energy lactation (NEL) decreased remarkably from variant 8 to variant 15 in a high range comprised between 7.2 and 6.2 MJ kg^{-1} DM. The values obtained for the crude fibre (CF) content were significantly different in all three variants, increasing steadily from 179 g kg^{-1} DM to 263 g kg^{-1} DM, in variant 8 and variant 15 significantly. The ether extract (EE) corresponds to the fats and fatty acids. It ranged from 30.6 to 40.4 g kg^{-1} DM and it was the lowest in the highest variant. The variant had a significant effect on the contents of structural carbohydrates measured as neutral detergent fibre (NDF) and acid detergent fibre (ADF). NDF varied between 410 and 500 g kg^{-1} DM in variant 8 and variant 15 respectively, and ADF followed the same trend between 236 and 312 g kg^{-1} DM. Non fibre carbohydrates (NFC) content, also called non-structural carbohydrates (starch, sugars), was similar in all three variants, around 200 g kg^{-1} DM.
Only CA, EE, and OM contents showed significant differences between Beifeld and Stallfeld but the differences in least squares means were very low (0.6 % in CA, 0.19 % in EE and 0.6 % in OM).

Table 7: Crude nutrients, structural carbohydrates and energy contents in the grass at different cutting heights.

	Variant					Field			
	Least Squares Means			Std Error	P	LSM		Std Error	P
	8	11	15			Beifeld	Stallfeld		
CA (g kg^{-1}DM)	111^{b}	110^{b}	98^{a}	2	0.0007	103^{a}	109^{b}	1	0.015
CP (g kg^{-1}DM)	235^{b}	202^{a}	175^{a}	7	0.0002	201^{a}	206^{a}	5	0.546
CF (g kg^{-1}DM)	179^{a}	211^{b}	263^{c}	6	<0.0001	221^{a}	214^{a}	5	0.316
EE (g kg^{-1}DM)	39.2^{b}	40.4^{b}	30.6^{a}	0.6	<0.0001	35.8^{a}	37.7^{b}	0.5	0.017
OM (g kg^{-1}DM)	890^{a}	890^{a}	902^{b}	2	0.0007	897^{b}	891^{a}	1	0.015
NDF (g kg^{-1}DM)	410^{a}	452^{b}	500^{c}	10	0.0002	464^{a}	443^{a}	8	0.085
ADF (g kg^{-1}DM)	236^{a}	281^{b}	312^{c}	7	<0.0001	271^{a}	282^{a}	5	0.198
NFC (g kg^{-1}DM)	205^{a}	196^{a}	198^{a}	8	0.712	195^{a}	204^{a}	7	0.373
NEL (MJ kg^{-1}DM)	7.2^{c}	6.7^{b}	6.2^{a}	0.1	<0.0001	6.7^{a}	6.7^{a}	0.1	0.587

$^{a-c}$Least squares means within a row without a common superscript differ significantly ($P < 0.05$)

II. Discussion

The rise in temperatures in April was very fast and sudden. The period of time between the last day with a temperature below 0°C (11th April) and the first day with a temperature above 25°C (26th April) was the shortest ever recorded since 1872 (ZAMG, 2013).

It is a well-known phenomenon in clover swards, to grow stronger in the course of the vegetation period. It has been observed in a grassland trial in Czech Republic as well (Pozdisek et al., 2011). Yet, legume swards showing a bottom-up increase in density (Laca *et al.,* 1992), the higher coverage of clover in the later harvests suggests that cows could take heavier bites at that time of the vegetation period, influencing ingestion rates. The coverage of *Poa pratensis* on the contrary showed a clear decrease between harvest 1 and 2. This effect of the vegetation time on this species in particular has not been observed in other trials and it could be therefore only the effect of the change to the next area in the course of the trial.

The variations in botanical composition between fields can be explained by slightly different management strategies. In fact *Lolium perenne* and *Poa pratensis* had been reseeded in Beifeld every year between 2007 and 2010 (7 kg ha^{-1} *Poa pratensis* variety LATO, 3 kg ha^{-1} *Lolium perenne* variety GURU), but not in Stallfeld. The high coverage of *Poa supina* in Beifeld and *Agrostis stolonifera* in Stallfeld (over 10% each) can represent an issue for the quality of the pasture in case of change in management. A reduction of fertilisation use in particular would favour these two species able of spreading very quickly via aboveground stolons, at the expense of longer-lived plants such as *Poa pratensis* (Angeringer *et al.,* 2011, Starz, oral communication).

Despite different botanical compositions the fields had similar sward structures and productivities because the dominant species recorded in both fields have similar growing patterns (Starz, oral communication).

There are different methods to measure sward height (ruler/stick, rising plate meter or RPM) but the results are not comparable between methods. In fact, when using the RPM, the values equal 50% to 70% of the values obtained with the ruler, depending on species composition and sward density (ASTA, 2011). It is thus important that the same method is being used over the whole experiment.

A high LAI indicates an effective use of sunlight and a high density of biomass. The decrease in leaf area index over time can be linked to the decreased average pre-cutting height and to general changes during vegetation period. The intermediate LAI in harvest 3 is probably due to the increased coverage of white clover (and its three-leaved structure) counterbalancing the effect of lower average sward height. The behaviour of the LAI being similar to the one of the density, the results confirm that leaf area index measurements are a reliable method for canopy density estimation.

The values of density observed in this trial are very high when compared to the ones found in the literature, ranging from 571 to 2,969 g m^{-3} (Laca *et al.,* 1992). It has been suggested in the course of the trial that this could be due to the very short post-cutting heights (between 3.3 cm and 4.5 cm) (Tab. 5) obtained when using the hand-mower. Knowing that grass species made up about 70 % of the swards and that grass swards density is higher in the areas directly close to the ground, the high densities in our experiment could be an effect of the method used. To test this hypothesis, a small experiment (described in annex I) has been carried out in parallel to the main trial. Instead of looking at pre-cutting heights, this experiment focused on the effect of two depths, namely 3-4 cm and 5-6 cm, on the dry matter yield and consequently on the density. The results suggest that the deep cutting height might indeed have influenced the density. But these results shall only serve as help for the interpretation of the densities recorded in the main trial rather than proof, as no strictly scientific procedure had been implemented.

It is now well established that grazing cows cannot graze deeper than 5-6 cm from the ground and our results might thus be biased in terms of implementation to a scenario with cattle. However given the fact that the same error has been done in all three variants (no significant effect of the variant on post-cutting height) (Tab. 5a), the deeper cutting height does not question the validity of the trial.

Knowing the productivity of a pasture, the next step is to adapt management. The dry matter yields in this trial are higher than the ones found in the literature. Eastes *et al.* have found an average grass cover between 1,800 and 2,200 kg DM ha^{-1} in Switzerland (Eastes *et al.,* 2009). Pre-grazing dry matter mass on the paddock should not be too high to avoid as wastage and optimize pasture utilization. A pre-grazing mass between 1,600 and 2,400 kg DM ha^{-1} is considered correct according to Roca-Fernández *et al.,* 2010.
In dairy cows with an average milk production of 20 kg day^{-1}, the amount of grass ingested every day is approximately 15 kg DM. Increasing pre-grazing height from 8 to 15 cm in such a scenario can result in 15 more cows grazing per hectare and per day (Tab. 8).

Tab. 8: Guideline for rotational grazing of dairy cows, for target daily feeding level of 15 kg cow^{-1} (Holmes *et al.*, 2002; own calculations)

	Variant 8	11	15
Pre-grazing pasture yield (kg ha^{-1})	1,613	2,206	2,894
Daily pasture allowance (kg DM cow^{-1})	45	45	45
Cows grazed per day (cow ha^{-1})	35	50	65
Area offered per cow daily (m² cow^{-1})	290	200	150

Given the very high yields in each harvest, the total dry matter yield is also higher than expected, considering the late start of the vegetation growth this year (8th of April approximately). Providing that there will not be abnormally early snowfalls this year, the annual yield in 2013 is likely to reach the ones from the previous years, presented in Starz *et al.,* 2010 and ranging from 9.0 t ha^{-1} to 11.0 t ha^{-1}.
The results of growth rate presented in Tab. 6 are similar to the average daily grass growth of 75 kg ha^{-1} recorded in Switzerland by Mosimann *et al.* in 2010 but the aspect of the annual grass growth chart is very characteristic of the year 2013. The late start of the growing season and the very sudden shift from winter to spring put together explain the kick-in of the biomass growth generating such a curve. The heavy precipitations in May and June can at least partly explain the sudden slow-down in grass growth observed in this period.

The very high contents of crude protein and energy overall the trial confirm that it is possible to produce very good quality forage for dairy cows in an organic system under harsh Alpine conditions. In variant 8 particularly, the NEL content never got below 7 MJ kg^{-1} DM which is nearly in the range of concentrates feeds and relevant with previous findings in the same area (Starz *et al.,* 2011).
The increase in crude fibre between variant 8 and 11, and between variant 11 and 15 is a natural phenomenon due to the ageing of the sward, known as 'age effect' (Beever *et al.,* 2000). It is characterised by an increase in the proportion of cell walls (mainly structural carbohydrates) at the expense of the cell contents (proteins and non-structural carbohydrates). While crude fibre content increases from 17.9 % to 26.3 %, proteins drop from 23.5 % to 17.5 % (Tab. 7).
Structural carbohydrates play an important role for fulfilment of fibre requirements to ruminants. According to the Nutrient Requirements of Dairy Cattle (NRC, 2001), the minimum recommended NDF should be at least between 250 and 330 g kg^{-1} in the whole ration of dairy cows and it was achieved in every variant in this trial. (Starz *et al.,* 2011). In this case, high supplementation of concentrates is limited in pasture based feeding systems.
The results of this trial are in the highest range in terms of forage feeding value compared to other grassland trials carried out in the Alpine region (Gruber *et al.,* 2011; Starz *et al.,* 2011).

CONCLUSION

Implementing a grass-based dairy production system in mountainous region is the current objective of organic farms in the Austrian Alps. Because of the harsh climate, the short vegetation period, and the lack of good quality arable land, dairy production is one of the main activities in those regions, with tourism. The low costs of grazed grass compared to concentrates and the good image of milk produced with pasture, allow these products to be sold as premium goods on the market and support the activities of farmers. This trial looked at different grass growth heights in the aim of implementing a seasonal rotational grazing system adapted to the particular environmental conditions found in the Alps. The results showed that despite a very late start of the growing season (mid-April), the strong grass growth rate (between 66 and 81 kg DM $ha^{-1}day^{-1}$) in the first part of the experiment allowed high dry matter yields making it possible to provide sufficient forage for lactating dairy cows. The density of the swards, overall higher than 250 kg ha^{-1} cm^{-1} suggests that these swards, typical of Alpine pastures offer a forage structure in favour of higher ingestion rate through heavy bites. The nutritive value of the forage in this trial was more than satisfying, with net energy lactation over 7 MJ kg^{-1} DM and a crude protein content of 235 g kg^{-1} DM for the shorter swards. As for the fibre content, it was always within the range recommended or ruminants. These results confirm that when well-managed, Alpine pastures can provide the high quality forage necessary to fulfil the requirement of high producing dairy cows. Grassland management is important to make the best of good genetics but every genotype is not adapted to such a system. Another important research field in the Alps is to find the cow genotype to fit a grass-based scenario, emphasizing, among other aspects, on lower body-weight and a higher fertility (Horn *et al.,* 2013).

References

Articles

Angeringer, W., Starz, W., Pfister, R., Rohrer, H., Karrer, G. 'Vegetation change of mountainous hay meadows to intensified management regime in organic farming'. In: Pötsch, E. M., Krautzer, B., Hopkins, A. (eds) (2011) *Grassland Farming and Land Management Systems in Mountainous Regions*. Grassland Science in Europe 16, 353-355.

Basset-Mens, C., Ledgard, S., Boyes, M. (2009) *Eco-efficiency of intensification scenarios for milk production in New Zealand*. Ecological Economics 68, 1615-1625.

Bassler, G., Angeringer, W., Karrer, G., Schaumberger, A., Formayer, H. 'Change of plant species composition in mountainous meadows against the background of climate change and altered management'. In: Pötsch, E. M., Krautzer, B., Hopkins, A. (eds) (2011) *Grassland Farming and Land Management Systems in Mountainous Regions*. Grassland Science in Europe 16, 547-549.

Bohner, A. (2007) *Phytodiversität im Wirtschafts- und Extensivgrünland der Tallagen*. Biodiversität in Österreich, 28. Juni 2007, 29-36.

Bohner, A., Starlinger, F., Koutecky, P. (2012) Vegetation changes in an abandoned montane grassland, compared to changes in a habitat with low low-intensity sheep grazing – a case study in Styria, Austria. Journal on Protected Areas Research and Management 4, 5-12.

Buchgraber, K., Schaumberger, A., Pötsch, E. M. 'Grassland farming in Austria – Status quo and future prospectives'. In: Pötsch, E. M., Krautzer, B., Hopkins, A. (eds) (2011) *Grassland Farming and Land Management Systems in Mountainous Regions*. Grassland Science in Europe 16, 13-24.

Butler, G., Nielsen, J. H., Larsen, M. K., Rehberger, B., Stergiadis, S., Canever, A., Leifert, C. (2011) *The effects of dairy management and processing on quality characteristics of milk and dairy products*. NJAS - Wageningen Journal of Life Sciences 58, 97-102.

Collomb, M., Bisig, W., Bütikofer, U., Sieber, R., Bregy, M., Etter, L. (2008) *Fatty acid composition of mountain milk from Switzerland: Comparison of organic and integrated farming systems*. International Dairy Journal 18, 976-982.

Couvreur, S., Hurtaud, C., Lopez, C., Delaby, L., Peyraud, L. (2006) The linear relationship between the proportion of fresh grass in the cow diet, milk fatty acid composition, and butter properties. Journal of Dairy Science 89, 1956-1969.

Dillon, P., Snijders, S, Buckley, F., Harris, B., O'Connor, P., Mee, J. F. (2003) A comparison of different dairy cow breeds on a seasonal grass-based system of milk production 2. Reproduction and survival. Livestock production Science 83, 35-42.

Dillon, P., Hennessey, T., Shalloo, L., Thorne, F., Horan, B. (2008) Future outlook for the Irish dairy industry: a study of international competitiveness, influence of international trade reform and requirement for change. International Journal of Dairy Technology 61, 16-29.

Distel, R. A., Laca, E. A., Griggs, T. C., Demment, M. W. (1995) *Patch selection by cattle: maximization of intake rate in horizontally heterogeneous pastures*. Applied Animal Behaviour Science 45, 11-21

Eastes, D., Thomet, P., Mosimann, E., Käch Pitt, S., Pitt, J. (2009) Optimiser la qualité de l'herbe pour plus de performances en pâture tournante. 2. Application à une exploitation Suisse. Revue Suisse Agricole 41, 113-118.

Eriksen, J., Ledgard, S., Luo, J., Schils, R., Rasmussen, J. (2010) *Environmental impacts of grazed pastures.* Grassland Science in Europe 15, 880-890.

Fleury, P., Petit, S., Mattanovich, E., De Ros, G., Miéville-Ott, V. (2004) *Constructing sustainable agriculture at local level. Insights from small-scale farming in the Alps.* (Pre)Proceedings of the 6th European IFSA Symposium, 243-258.

Greimel, M. (2002) *Einsparungspotentiale in der Grundfutterkonservierung*. 8. Alpenländisches Expertenforum, 9. -10. April 2002, Bundesanstalt für alpenländische Landwirtschaft Gumpenstein, A-8952 Irdning, 77-80.

Gruber, L., Schauer, A., Häusler, J., Urdl, M., Adelwöhrer, A., Südekum, K.-H. (2011) Influence of growth stage of permanent grassland on dry matter yield, nutritive value, feed intake and milk yield of dairy cows during the whole period of vegetation. Grassland Science in Europe 16, 136-138.

Gruber, L., Häusler, J., Steinwidder, A., Schauer, A., Maierhofer, G. (2006) Influence of cutting frequency in Alpine permanent grassland on nutritive value, DM yield and agronomic parameters of milk production. Slovak Journal of Animal Science 39, 26-42.

Harris, S. L., Clark, D. A., Auldist, M. J., Waugh, C. D., Laboyrie, P. G. (1997) *Optimum white clover content for dairy pastures*. Proceedings of the New Zealand Grassland Association 59, 29-33.

Hopkins, A. 'Mountainous farming in Europe'. In: Pötsch, E. M., Krautzer, B., Hopkins, A. (eds) (2011) *Grassland Farming and Land Management Systems in Mountainous Regions*. Grassland Science in Europe 16, 3-12.

Horn, M., Steinwidder, A., Gasteiner, J., Podstatsky, L., Haiger, A., Zollitsch, W. (2013) Suitability of different dairy cow types for an Alpine organic and low-input milk production system. Livestock Science. Available online [ScienceDirect] at: http://dx.doi.org/10.1016/j.livsci.2013.01.011

Johansen, A. (2010) Growth and quality of multispecies pastures harvested at a fixed sward height. Grassland Science in Europe 15, 961-963.

Kolver, E. S., Muller, L. D. (1998) Performance and nutrient intake of high producing Holstein dairy cows consuming pasture or a total mixed ration. Journal of Dairy Science 81, 1403-1411.

Laca, E. A., Ungar, E. D., Seligman, N., Demment, M. (1992) *Effects of sward height and bulk density on bite dimensions of cattle grazing homogeneous swards*. Grass and Forage and Science 47, 91-102.

Lobsiger, M., Wyss, U., Réviron, S., Stoll, W. (2010) *Values and image of pasture-based milk production systems*. Grassland Management in Europe 15, 118-120.

McCarthy, B., Delaby, L., Pierce, K. M., Journot, F., Horan, B. (2011) Meta-analysis of the impact of stocking rate on the productivity of pasture-based milk production systems. Animal 5, 784-794.

McEvoy, M., O'Donovan, M., Wims, C., Kennedy, E. (2010) *The effect of evaluation protocol on the dry matter yield performance of Lolium perenne varieties*. Grassland Science in Europe 15, 314-316.

McEvoy, M., O'Donovan, M., Kennedy, E., Murphy, J. P., Delaby, L., Boland, T. M. (2008) *Effect of pregrazing herbage mass and pasture allowance on the lactation performance of Holstein-Friesian dairy cows*. Journal of Dairy Science 92, 414-422.

Milne, J. A. (2005) Societal expectations of livestock farming in relation to environmental effects in Europe. Livestock Production Science 96, 3-9.

Minns, A., Finn, J., Hector, A., Caldeira, M., Joshi, J., Palmborg, C., Schmid, B., Scherer-Lorenzen, M., Spehn, E., Troumbis, A., and the BIODEPTH project (2001) The functioning of European grassland ecosystems: potential benefits of biodiversity to agriculture. Outlook on AGRICULTURE 30(3), 179-185.

Mosimann, E., Schmied, R., Thomet, P. (2010) *Beef fattening on grazed leys: interest of tall fescue.* Grassland science in Europe 15, 976-978.

Pavlu, V., Hejcman, M., Pavlu, L., Gaisler, J., Nezerkova, P. (2006) *Effect of continuous grazing on forage quality, quantity and animal performance*. Agriculture, Ecosystems and Environnement 113, 349-355.

Peyraud, J. L., Van den Pol-van Dasselaar, A., Dillon, P., Delaby, L. (2010) *Producing milk from grazing to reconcile economic and environmental performances*. Grassland Science in Europe 15, 865-879.

Pötsch, E. M., Resch, R., Häusler, J., Steinwidder, A. (2010) Productivity and floristic diversity of a contiuous grazing system on short swards in mountainous regions of Austria. Grassland Science in Europe 15, 988-990.

Pötsch, E. M., Blaschka, A., Resch, R. 'Impact of different management systems and location parameters on floristic diversity in mountainous grassland'. In: Lillak, R., Viiralt, R., Linke, A., Geherman, V. (2005) *Integrating Efficient Grassland Farming and Biodiversity, Proceedings of the 13th Symposium of EGF 2005*. Grassland Science in Europe 10, 315-318.

Pozdísek, J., Látal, O., Stýbnarová, L. (2010) Voluntary intake of forages from permanent grasslands with different quality in suckler cows. Grassland Science in Europe 15, 991-993.

Pulido, R. G., Leaver, J. D. (2003) Continuous and rotational grazing of dairy cows – the interactions of grazing system with level of milk yield, sward height and concentrate level. Grass and Forage Science 58, 265-275.

Prache, S. & Peyraud, J.-L. (1997) *Préhensibilité des l'herbe pâturée chez les bovins et les ovins.* INRA Productions Animales 10 (5), 377-390.

Raison, C., Chambault, H., Le Gall, A., Pflimlin, A. (2008) Impact du système fourrager sur la qualité de l'eau. Enseignements issus du projet Green Dairy. Fourrages 193, 3-18.

Ribeiro Filho, H. M. N., Delagarde, R., Peyraud, J. L. (2005) Herbage intake and milk yield of dairy cows grazing perennial ryegrass swards or white clover/perennial ryegrass swards at low- and medium-herbage allowances. Animal Feed Science and Technology 119, 13-27.

Roca-Fernandez, A. I., O'Donovan M., Curran, J., Gonzalez-Rodriguez, A. (2010) *Effect of two pre-grazing herbage masses and daily herbage allowances on perennial ryegrass sward characteristics.* Grassland Science in Europe 15, 994-996.

Sanderson, M. A., Soder, K., Brzezinski, N., Goslee, S., Skinner, H., Wachendorf, M., Taube, F., Muller, L. 'Diverse forage mixtures effect on herbage yield, sward composition, and dairy cattle performance'. In: Murphy, J. J. (ed.) (2005) *Utilisation of grazed grass in temperate animal systems*, 162.

Schaumberger, A. (2010) *Forschungsbericht. Räumliche Modelle zur Vegetations- und Ertragsdynamik im Wirtschaftsgrünland*. Dissertation zur Erlangung des akademischen Grades eines Doktors der technischen Wissentschaften an der Technischen Universität Graz.

Schermer, M. (2004) *The concept of eco-regions in Austria.* (Pre)Proceedings of the 6th European IFSA Symposium, 173-183.

Schori, F. (2009) Weidebesatzstärken: Auswirkung auf milchleistung und grasqualität. Agrarforschung 16, 436-441.

Soder, K. J., Sanderson, M. A., Stack, J. L., Muller, L. D. 'Intake and milk production of lactating dairy cows grazing diverse forage mixtures over two grazing seasons'. In: Murphy, J. J. (ed.) (2005) *Utilisation of grazed grass in temperate animal systems*, 164.

Starz, W., Steinwidder, A., Pfister, R., Rohrer, H. (2011) *Forage feeding value of continuous grazed sward on organic permanent grassland*. Grassland Science in Europe 16, 356-358.

Starz, W., Steinwidder, A., Pfister, R., Rohrer, H. (2010) *Continuous grazing in comparison to cutting management on an organic meadow in the eastern Alps*. Grassland Science in Europe 15, 1009-1011.

Steinwidder A., Schneider M., Wachendorf M., Starz W., Pötsch E.M. (2011) *The future of organic grassland farming in mountainous regions of Central Europe.* Grassland Science in Europe 16, 286-296.

Steinwidder, A., Starz., W., Podstatzky, L., Kirner, L., Pötsch, E. M., Pfister, R., Gallnböck, M. (2010) Changing towards a seasonal low-input pastoral dairy production system in mountainous regions of Austria – results from pilot farms during reorganisation. Grassland Science in Europe 15, 1012-1

Wims, c., McEvoy, M., Boland, T., O'Donovan, M. (2010) *A comparison between cut and intensively grazed swards on dry matter yield of perenniel ryegrass*. Grassland science in Europe 15, 578-580.

Books

Beever, D. E., Offer, N., Gill, M. (2000) 'The feeding value of grass and grass products', in: Hopkins, A. (ed.) *Grass, its production and utilization*. 3rd Edition, Oxford: Blackwell Science, 140-195.

Holmes, C. W., Brookes, I. M., Garrick, D. J., Mackenzie, D. D. S., Parkinson, T. J., Wilson, G. F. (2002) *Milk production from pasture, principles and practices*. Palmerston North: Massey University. 601pp.

Mayne, C. S., Wright, I. A., Fisher, G. E. J. (2000) 'Grassland management under grazing and animal response' in: Hopkins, A. (ed.) *Grass, its production and utilization*. 3rd Edition, Oxford: Blackwell Science. 247-291.

Rook, A. J. (2000) 'Principles of foraging and Grazing behaviour', in: Hopkins, A. (ed.) *Grass, its production and utilization*. 3rd Edition, Oxford: Blackwell Science, 229-246.

Other references

Administration des Services Techniques de l'Agriculture (ASTA) (2011) *De l'herbe au lait.* Journées internationales de la prairie.

Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (BMLFUW)

- (2012) Zahlen und Fakten – Entwicklung Biologische Landwirtschaft. Available at: www.lebensministerium.at/land/bio-lw/zahlen-fakten/Bio_Produktion.html (Accessed: 06/03/2013)

Digitaler Atlas Steiermark (2013) Höhen- und Reliefkarte. Available at: www.gis.steiermark.at/cms/ziel/50190666/DE/

European Commission

- (2010) *EU dairy farms report 2010. Based on FADN data*. Available at: ec.europa.eu/agriculture/rica/pdf/Dairy_report2011.pdf
- Rohner-Thielen, E. (2008) *From grass to glass, a look at the dairy chain*. Eurostat – Statistics in focus. Available at: epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-SF-08-076/EN/KS-SF-08-076-EN.PDF
- Martinez-Palou, A. & Rohner-Thielen, E. (eds) (2011), *Food: From farm to fork statistics*. Eurostat Pocketbooks. 2011 edition. Available at: epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-32-11-743/EN/KS-32-11-743-EN.PDF
- Eurostat (2005-2012) Datenbank – Landwirtschaft. Available at: epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database (Accessed: 27/05/2013

NRC (2001) *Nutrient Requirements for Dairy Cattle*. National research Council, Washington DC: National Academy Presse, 37.

ZAMG (2001) *Klimadaten von Österreich 1971 – 2000*. Available at: www.zamg.ac.at/fix/klima/oe71-00/klima2000/klimadaten_oesterreich_1971_frame1.htm (Accessed: 20/06/2013)

Oral communications

Starz W. about the changes in botanical composition

Annex

<u>Annex I:</u> Experimental procedure to test the influence of cutting depth on dry matter density of the swards