Rit LbhÍ nr. 10

Timothy productivity and forage quality

- possibilities and limitations -

NJF Seminar 384
10 – 12 August 2006
Akureyri, Iceland

Landbúnaðarháskóli Íslands
Agricultural University of Iceland

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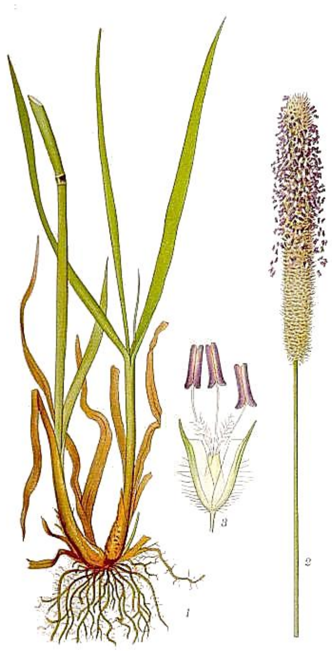

TIMOTEJ, PHLEUM PRATENSE L.

Landbúnaðarháskóli Íslands
Agricultural University of Iceland

Nordic Association of Agricultural Scientists

Phleum pratense L.

English:	Timothy (Herds grass [USA, old])
Danish:	Eng-Rottehale, Timoté
Faeroish:	Eingjar timotey
Finnish:	Nurmitähkiö, timotei
French:	Fléole des prés
German:	Wiesen-Lieschgras
Icelandic:	Vallarfoxgras, (rottuhali, túnskollapuntur [old])
Lithuanian:	Pašariniai motiejukai
Norwegian:	Timotei
Swedish:	Ängskampe, vanlig timotej

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Seminar Program

Friday August 11

Keynote presentations

Varieties

Posters

Saturday August 12

Physiology and management

09.00-09.30	**Phenological development and aging of timothy swards as assessed by the numeric index mean stage by count** - Anne Kjersti Bakken, T. Lunnan, O. Harbo, A. K. Bergjord & H. Bonesmo …………………………………………………………… 61
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10.30-11.00	**The effect of management and accompanying grasses on the persistence of timothy** – Hólmgeir Björnsson …………………………………………………………………….... 69
11.00-11.30	**Fluctuations in the timothy population in mixed swards according to harvesting regime** – Anne Kjersti Bakken, T. Lunnan & O. Harbo …………………………………..… 74
11.30-12.00	**Improving seed production of organic timothy (*Phleum pratense*) – the preliminary results of an advisory campaign in Sweden** - Thorsten Rahbek Pedersen …………..…….. 78
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Feed quality

13.00-13.25	**Digestibility of timothy** - Guðni Thorvaldsson ……………………………………….…... 85
13.25-13.50	**Superior yield and nutritive value of timothy grown under cool temperatures** – Annick Bertrand, Castonguay Y., Tremblay G.F. & Bélanger G.……………………...……. 89
13.50-14.15	**Morphological aspects of digestibility of timothy** - Anne - Maj Gustavsson …………….. 92
14.15-14.40	**The effect of timothy growth stage at harvest on fermentation characteristics in round bale silage and voluntary feed intake in dairy cows** - Thóroddur Sveinsson & L. Bjarnadóttir …………………………………………………………………………….. 96
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15.00-15.30	Coffee
15.30-16.30	**Conclusion panel**
16.30	**Seminar closure**
19.30	**Seminar banquet at Hótel Edda**

Posters

Keynote presentations

Dalabóndinn í óþurrknum

Hví svo þrúðgu þú
þokuhlassi
súldanorn
um sveitir ekur?
Þér man eg offra
til árbóta
kú og konu
og kristindómi.

Jónas Hallgrímsson (1807-1845)

The Farmer in Wet Weather

Goddess of drizzle,
driving your big
cartloads of mist
across my fields!
Send me some sun
and I'll sacrifice
my cow --- my wife ---
my Christianity!

translated by Dick Ringler

Timothy – the saviour of Icelandic agriculture?

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The Agricultural University of Iceland, aslaug@lbhi.is

Introduction

Timothy (*Phleum pratense* L.) is the most important forage grass in Icelandic agriculture. No other species matches it when we simultaneously look at such factors as yield ability, feed quality, palatability and persistence (e.g. Sveinsson 2001). Timothy is a naturalized species in Iceland (Stefánsson 1948) and its distribution is mostly limited to cultivated pastures, roadsides and residential areas. Even though timothy was first included in agricultural experiments already in 1898 (Friðriksson, 1956), it wasn't exploited in agriculture until much later, as winter hardy and persistent cultivars were lacking. The cultivars Grindstad (from Norway) and Øtofte (from Denmark) were first imported in 1955 (Óskarsson, unpublished data) but they showed poor winter survival and soon disappeared from the market. It wasn't until Engmo from Troms in Norway arrived on the scene in 1962 and later the two Icelandic cultivars, Korpa (in 1970) and Adda (in 1982), that farmers began to enjoy the benefits of timothy. Since then it has steadily grown in popularity and now completely dominates the forage seed market.

In this paper we will attempt to shed light on the role that timothy has played in the development of agricultural production in the country over the years. We will speculate whether recent advances in milk production can be contributed to its presence in the feed production system. In our speculations we will make use of the statistics collected through the centralized milk recording system by the Farmers Association and Agricultural Authority of Iceland. However, it is important to point out that these statistics are not altogether comparable and therefore our findings will only be indicative rather than conclusive. We will also look briefly at novel uses of timothy in modern multifunctional agriculture.

Agriculture in Iceland in a historical light

The development of agriculture in Iceland from the time of the settlement in the late ninth century to the present day can be divided into five distinct phases which are reflected in the production of farm produce (Figure 1):

I: 900-1900 Self-sufficiency

For centuries sheep husbandry was the main farming activity in Iceland and productivity was very low. Hay was made up of indigenous species obtained from wild pastures and bog lands. It has been estimated that the country could carry 360 thousand sheep by utilizing grazing all year round and hay obtained from bogs in more difficult years. This was sufficient to maintain a population of 60 thousand (see Guðbergsson 1996).

II. 1900-1945. Cultivation begins

The growing urban population created a market for agricultural products. Food security was the major political driver for agriculture. Farmers adopted new but primitive technology in hay making and in improvements of hay fields. Artificial fertilizers arrived on the scene.

III. 1945-1980. Technological advances, increased production

After the end of World War II the rural population decreased rapidly and a subsidy system was set up to reward increased production. Advanced machinery was imported to reclaim new agricultural land. Agriculture was driven towards extensive cultivation of grassland seeded with introduced non-adapted grass cultivars and greater intensification with the use of artificial fertilizer and concentrates. Unfavourable climatic conditions in the 1960's caused severe winter kill in cultivated grasslands in many parts of the country.

IV. 1980-1995. Production restrictions
Overproduction, particularly in the sheep sector, called for revision of the extensive subsidy system. A quota system was introduced and farmers had to adapt to production limitations. A complete revision of the legal framework for agricultural policies was carried out in 1985. The main objectives were "to promote structural adjustment and increase efficiency in agricultural production and processing for the benefit of producers and consumers and to adjust the level of production to domestic demand and secure sufficient supply of agricultural products as far as practicable at all times" (Thorgeirsson 1996).

IV. 1995-2006. Improved efficiency
Food habits are changing and the proportion of local agricultural products in the total food budget becomes progressively lower. The drive is now towards maintaining margins by reducing inputs as well as by increasing outputs. Dairy and sheep production is steady but the number of "traditional" farms is declining, especially in the dairy sector. Increasing urban demand for rural estates is causing a significant rise in farmland prices. Farmers and other landowners are looking to alternative land uses in addition to food production and agriculture becomes progressively more multifunctional.

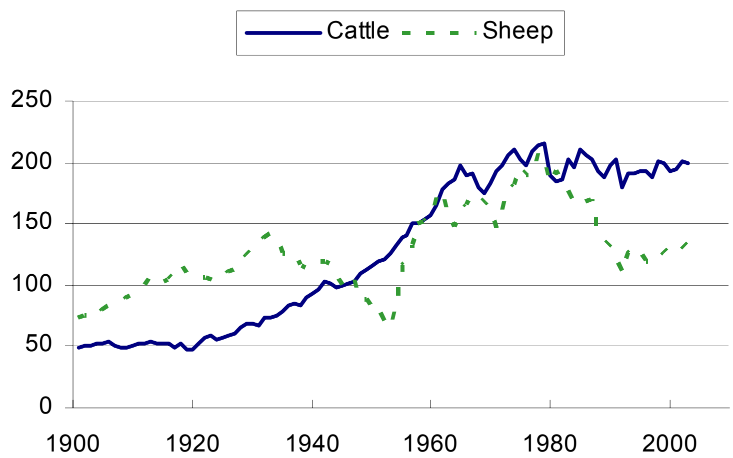

Figure 1. Relative changes in cattle and sheep production from 1901-2003. Volume index 1945=100.

Cultivation of grass fields

Cultivation of grass fields closely reflects the changes in agricultural production over the last 100 years. It commenced following legislation by the parliament in 1923, which provided support to farmers for the cultivation of new undisturbed land or drained bogs (Figure 2). The legislation coincided with the first importation of artificial fertilizer. The development was slow initially but advanced rapidly following World War II, when modern machinery arrived on the scene. It reached a maximum around 1965 (6000 ha yr^{-1}) but then began to slow down again, reaching a low point of around 800 ha yr^{-1}, according to records, when public support ceased in 1992. No state official records are thus available after that time. However, by estimating the extent of cultivation of grass fields from the imports of herbage seed, using the recommended seed rates, it can be seen that cultivation has increased substantially since 1995 compared to the situation just before 1990. In the early years the emphasis was on reclaiming new land for hay or silage, especially on drained bog land, rather than field renovation. Such land reclamation has completely ceased and from 1980 new cultivation has almost entirely been renovation of old cultivated grass fields.

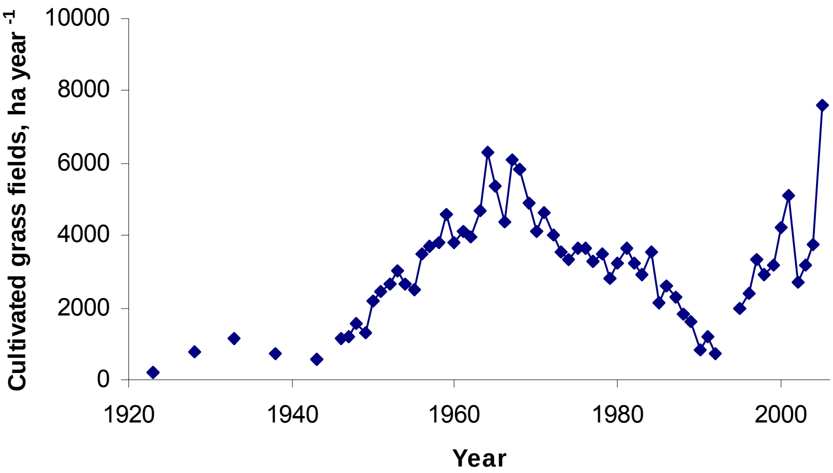

Figure 2. Annual cultivation of grass fields in Iceland 1921-1992 (from Helgadóttir 1996) and estimated area of cultivated grass fields 1995-2005, based on information on seed importation from the Agricultural Authority of Iceland.

Timothy in farmers' fields

Limited information is available on the exact forage species sown in the early days. However, sowing a mixture of several species was recommended, including timothy, meadow foxtail (*Alopecurus pratensis*), meadow grasses (*Poa pratensis*), fescues (*Festuca rubra*, *F. pratensis*), tufted hair-grass (*Deschampsia caespitosa*), perennial ryegrass (*Lolium perenne*) and even floating foxtail (*Alopecurus geniculatus*). The first records of seed imports from 1930 show that timothy and meadow foxtail each made up 35% of the recommended mixture. These two species seem to have dominated the seed mixtures, judging from advertisements from the seed merchants, but it wasn't until 1971 that detailed records became available on actual seed imports. Assuming a seed rate of 20 kg ha^{-1} for timothy it can be estimated that this species made up 40-60% of the total area sown in 1971-1990.

A detailed survey carried out on the species composition of Icelandic grass fields in 1990-1993 showed that timothy was the third most common species, judging either from the proportion of fields where it was found or from the average ground cover (Thorvaldsson 1994). The occurrence of timothy was, however, strongly dependent on geographic location, moisture content, degree of winter damage, elevation and not least the age of the sward. Thus it made up 60% of the ground cover in first year leys, 34% in fields between 2-5 years and 10% or less in fields older than 10 years.

Looking at seed imports from 1995 the amount of timothy has been steadily increasing and it can be estimated that timothy has made up 75-85% of the total area sown with forage grasses. This period warrants a closer look as the emphasis has been on improved efficiency of production. Judging by the renewed interest in the cultivation of grass fields (see Figure 2) it might therefore be worth exploring what role timothy has played in this development.

The contribution of timothy to recent advances in milk production

Big changes have been taking place in the Icelandic dairy sector over the last 10 years. After a long stagnation in total milk production there is an increased domestic demand for processed milk products calling for an increase in the production of fresh milk. At the same time there has been a big reduction in the number of dairy farmers but milk production per milking cow has, on the other hand, been increasing steadily (Figure 3).

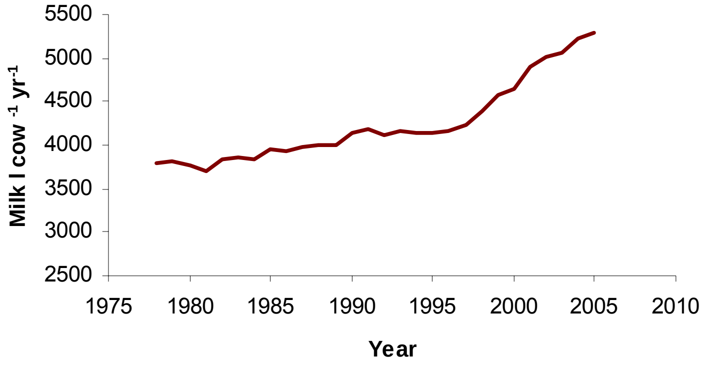

Figure 3. Annual average milk production per milking cow in Iceland as it appears in the milk recording system from 1978-2005 (Baldur H. Benjamínsson, personal communication).

There may be several explanations for a higher milk yield per animal. First, the digestibility of conserved feed has been steadily improving since around 1980 (Figure 4). The main reason for this is that farmers are harvesting the primary grass growth earlier (i.e. less mature) than before and, hence, the feed has a higher dry matter digestibility (DMD). Bale ensiling that was introduced in the late 1980's made this change possible and wilted round bale silage has since become the dominant curing method in Iceland.

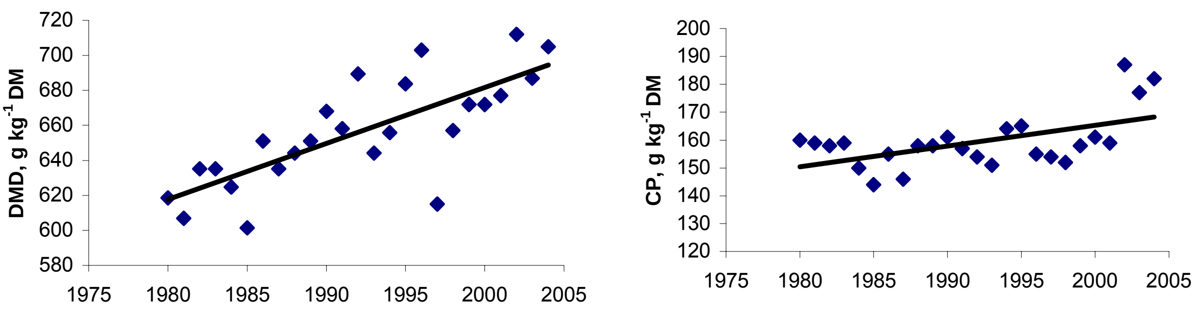

Figure 4. Mean digestibility (DMD) and mean crude protein (CP) of hay and silage samples from farms in north-east Iceland 1973-2004 (Gudmundur Helgi Gunnarsson and Thoroddur Sveinsson, personal communication).

The high feed values obtained after 1995 can without doubt be explained by the renewed interest in field renovation, where timothy plays a dominating role. Timothy has a clear quality advantage over other common grasses in Icelandic grass fields with a mean DMD of 726 g kg^{-1} DM compared to 679 g kg^{-1} DM from an old grass field with a mixture of indigenous grasses (based on results from experiments carried out over a 20 year period at

Korpa Experimental Station, see Helgadóttir & Hermannsson 2001). A series of Icelandic studies on the palatability of forage species for dairy cows revealed the superiority of timothy if harvested before mid heading (Sveinsson *et al.* 2001, Sveinsson & Bjarnadóttir 2006). These experiments recorded daily voluntary DM intake of timothy-based diets between 2.9-4.6% of live weight depending on the lactation stage and age of the cows. No other grass species tested could match this intake.

Secondly, barley grain production on dairy farms has been increasing steadily in the country from 1992 as a result of successful research and breeding of local cultivars (Figure 5). In summer 2005 barley was for example grown on 3600 ha by two thirds of all dairy producers (Hermannsson & Björnsson 2005). The use of concentrates has thus been increasing significantly by farmers over this period even though part of the increase can also be explained by increased importation of concentrates. It should be pointed out that extensive barley cultivation calls for a systematic crop rotation and that in itself ensures better quality of feed obtained from farmers' fields and in this timothy plays a major role (Helgadóttir & Hermannsson 2001).

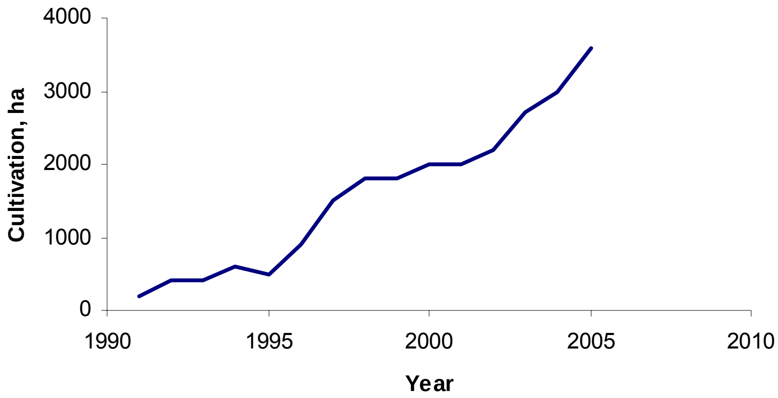

Figure 5. Annual cultivation of barley from 1991-2005.

Thirdly, increased milk yield per cow is also due to some extent to genetic gains in the local cattle populations. However, that discussion is outside the scope of the present paper.

Timothy as a feed for an ever-increasing horse population

Horse breeding for pleasure riding is presently a significant part of Icelandic agriculture. The urban horse population is becoming larger every year and demands quality feed. The Icelandic horse was brought from Norway 1100 years ago and has lived in isolation to the present day. It has adapted to a cold climate and survived harsh winters on poor fodder. It could be argued that the Icelandic horse has developed superior ability to digest and utilize roughage as a result of natural selection. And, indeed, horses have traditionally been given the poorest fodder on the farm. However, a recent study has shown that timothy can be considered a desirable feed for riding horses, especially if cut around the middle of July about two to three weeks after heading and made into wilted silage (Ragnarsson 2004). Such fodder seems to adequately fulfil the energy and protein requirements of active riding horses. Already, farmers specializing in fodder production for the urban horse market have adopted this forage system with good results.

Conclusions

Timothy did not become a real option for farmers in Iceland until winter hardy cultivars generally became available on the market around 1970. After that time it was used extensively for the establishment of new grass fields. However, its superior yield and quality over other forage species was not fully realized as grass fields were rarely renovated and timothy persisted poorly in permanent pastures. It is only in the last 10 years, partly with the advance of barley cultivation, that farmers are enjoying the benefits of timothy in their fields. The cultivation of barley calls for systematic crop rotation and timothy is the best option for leys lasting 5-6 years. Progressive dairy farmers have realized the importance of producing quality fodder and timothy certainly plays a significant part in the advances in milk production obtained over the last decade.

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The nutritive value of timothy and its improvement through management and breeding

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Introduction

Timothy (*Phleum pratense* L.) is a widely grown forage species in cool and humid regions of the world including north-eastern and north-western North America, Nordic countries, Russia, and Japan. It is also the most important perennial forage grass species grown in eastern Canada and it is grown in most provinces of western Canada.

The nutritive value of timothy is affected by controllable factors such as management practices, including harvest dates, maturity-based cultivar selection and fertilization, and by uncontrollable factors such as climatic conditions. As well, improvements in nutritive value can be achieved through breeding. In 2001, we published a review paper that summarized methods of controlling or improving the nutritive value of timothy through management and breeding, while keeping in mind the importance of yield (Bélanger *et al.* 2001). The paper focused primarily on N concentration, dry matter (DM) digestibility, and fibre concentration.

Although those parameters of nutritive value remain critical in forage-ruminant production systems, new parameters have come up in the last few years. The dietary cation-anion difference (DCAD) of forages fed to dry cows, the fatty acid composition of forages in relation to milk and meat quality, and protein characteristics in relation to N use efficiency by ruminants are now considered important characteristics of forages.

In this review, we present recent findings on several parameters of nutritive value of timothy in the context of management practices and breeding. Our review relies largely on research conducted in eastern Canada.

Digestibility and fibre concentrations

Forage dry matter digestibility remains an important parameter of nutritive value, particularly in intensive forage-ruminant systems. The digestibility of forage dry matter, estimated here by the *in vitro* true digestibility (IVTD), is a function of the concentration of the cell wall, estimated by the neutral detergent fiber (NDF) concentration, and the digestibility of that cell wall, estimated by the NDF digestibility (NDFD). In turn, the NDFD is a function of the proportion and linkages between hemicellulose, cellulose, and lignin.

The decrease in DM and cell wall digestibility and the increase in NDF concentration with increasing DM yield or maturity (Figure 1a) during a growth cycle of timothy were reported in several studies (Berg *et al.* 1996, Bélanger & McQueen 1996, 1998). Declines in DM digestibility of 2 to 7 g kg^{-1} DM d^{-1} (Berg *et al.* 1996, Thorvaldsson & Andersson 1986) or 0.30 to 0.36 g kg^{-1} DM $(°C\text{-}d)^{-1}$ (Thorvaldsson 1987, Bélanger & McQueen 1998) were reported. Rates of change in NDF digestibility and NDF concentration have also been estimated (Table 1; Bélanger & McQueen 1998). Decreases in DM and NDF digestibility with maturity are usually greater in spring than in summer, and greater under non-limiting than under limiting N conditions (Table 1).

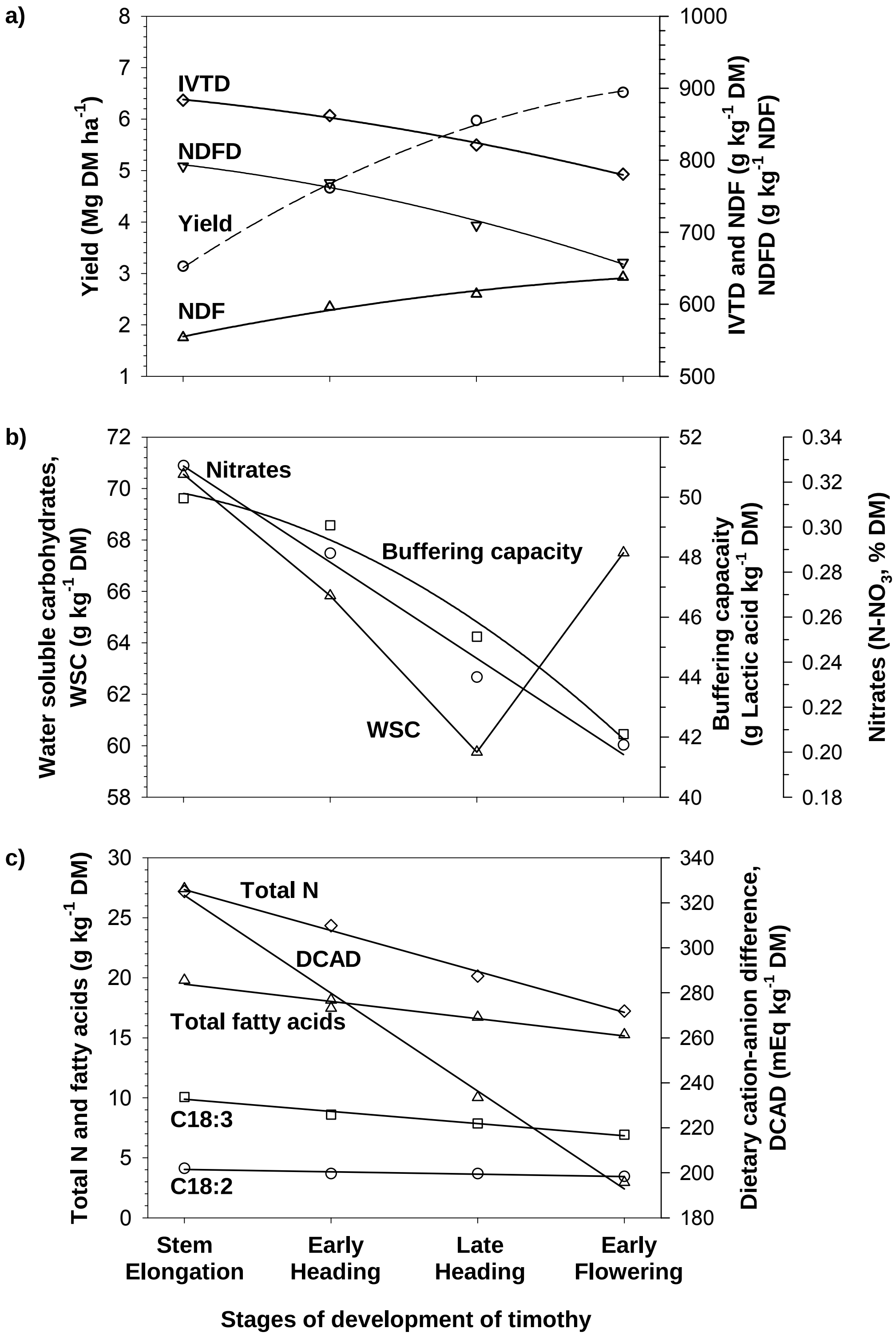

Figure 1. Effect of stages of development at harvest on forage DM yield and several parameters of nutritive value of timothy (adapted from Tremblay *et al*., 2005; Pelletier *et al*., 2006; Tremblay *et al*., 2006, and other unpublished data from an experiment in eastern Canada).

Table 1. Rates of change in *in vitro* true digestibility (IVTD), *in vitro* NDF digestibility (NDFD), and neutral-detergent fibre (NDF) concentration with maturity of timothy grown in spring and summer under limiting and non-limiting N conditions (adapted from Bélanger & McQueen 1998).

	Limiting N (INN[1] < 0.50)	Non-limiting N (INN > 0.90)
IVTD [g kg^{-1} DM (°C-d)$^{-1}$]		
spring	-0.16	-0.32
summer	-0.02	-0.16
NDFD [g kg^{-1} NDF (°C-d)$^{-1}$]		
spring	-0.20	-0.42
summer	-0.07	-0.22
NDF [g kg^{-1} DM (°C-d)$^{-1}$]		
spring	0.40	0.47
summer	-0.01	0.16

[1]The index of N nutrition is calculated as $N_{measured}/N_{critical}$, where $N_{critical}$ is the critical N concentration predicted by the model $N_{critical} = 48W^{-0.32}$, where W is the DM yield (Bélanger & Gastal 2000).

In recent years, this decline in DM and cell wall digestibility, and the increase in NDF concentration were successfully modelled. The Canadian Timothy Model (CATIMO) is a mechanistic simulation model of timothy growth and nutritive value calculated on a daily basis, taking into account solar radiation, temperature, soil water, and N availability. It is one of few models that simulates both forage growth (Bonesmo & Bélanger 2002a) and nutritive value (Bonesmo & Bélanger 2002b) with linkages to plant components. This model has been validated for timothy grown in eastern Canada (Bonesmo *et al*. 2005). The module on nutritive value has also been successfully integrated to the LINGRA-timothy model. Simulations with the combined model showed good agreements with measurements for timothy grown in Norway for NDF concentration, whereas the decline in NDFD was underestimated, probably due to daylength effects (Höglind & Bonesmo 2001).

The effect of N fertilization on timothy DM digestibility has been the subject of conflicting reports. Both negative and no effects of increasing N fertilization on DM digestibility were reported. Recent studies confirm the limited negative effect of increasing N fertilization on DM digestibility, NDF concentration, and NDFD (Figure 2a). However, in situations where N is very limiting to shoot growth (index of N nutrition < 0.5), the NDF concentration is less and the digestibility of the NDF is higher, resulting in a higher DM digestibility (Bélanger & McQueen 1998). In practical terms, adequate N fertilization has a positive effect on the relationship between nutritive value and DM yield. It is therefore a management practice that can be used to dissociate nutritive value and DM yield.

Forage nutritive value characteristics, such as DM digestibility, decrease with increasing DM yield. Cultivars with improved DM yield may have lower nutritive value, or conversely, cultivars with high nutritive value may have lower DM yield. In a study conducted in eastern Canada, the NDF concentration of 34 timothy cultivars increased with increasing DM yield (Figure 3). The study of genotypes (Brégard *et al*. 2001) also confirmed that more digestible genotypes tended to have a lower proportion of structural component, estimated by the NDF concentration or the proportion of true stems, and a lower DM yield. Considering both DM yield and nutritive value is therefore essential in timothy breeding programs.

Improvement in timothy digestibility can be achieved by reducing the proportion of the structural component (fibre or NDF concentration) and/or by increasing the digestibility

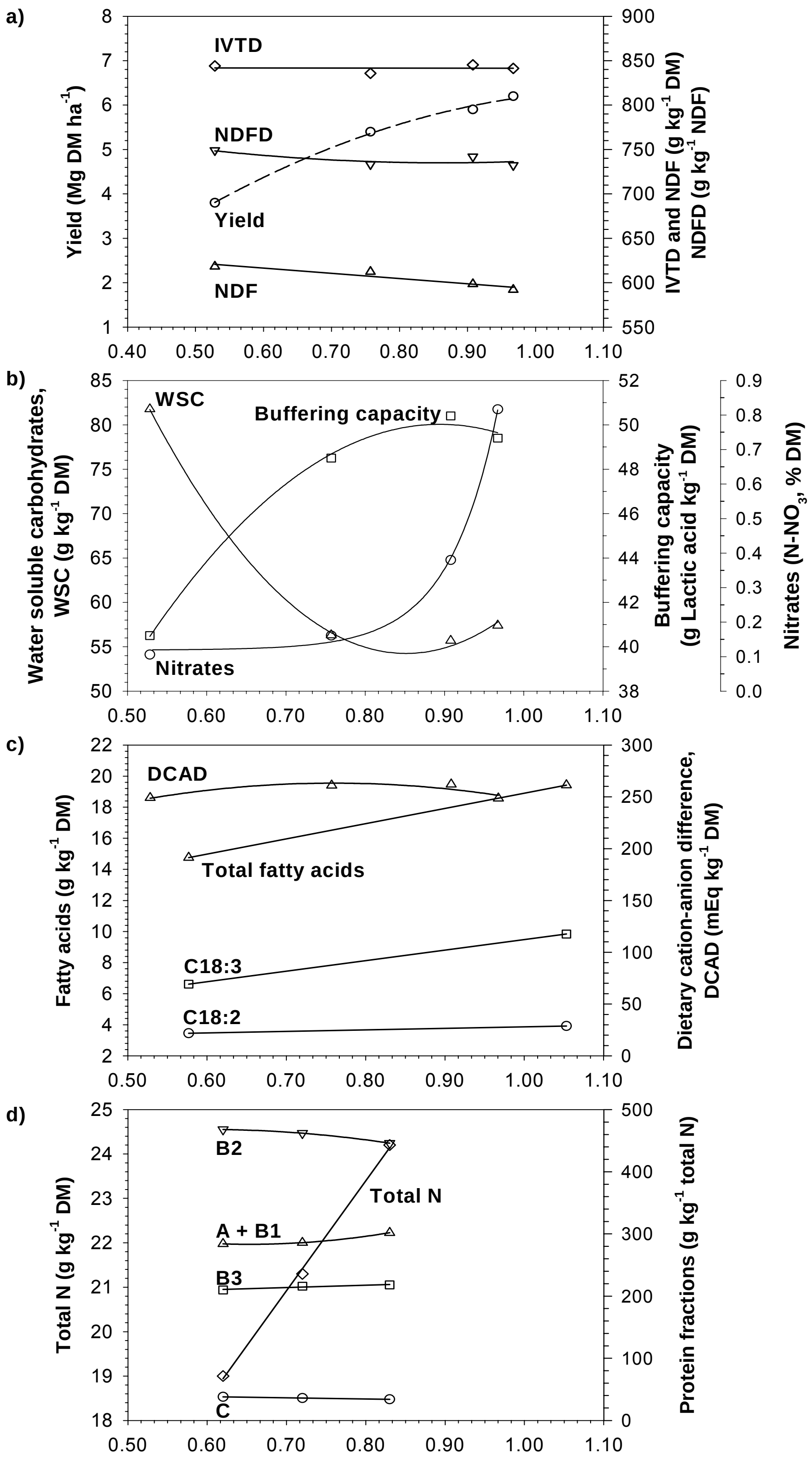

Figure 2. Effect of the level of N nutrition on forage DM yield and several parameters of nutritive value of timothy (adapted from Tremblay *et al*., 2005; Pelletier *et al*., 2006; Tremblay *et al*., 2006; Michaud *et al*., 2003; and other unplublished data from an experiment in eastern Canada). The index of N nutrition is calculated as $N_{measured}/N_{critical}$, where $N_{critical}$ is the critical N concentration predicted by the model $N_{critical} = 48W^{-0.32}$, where W is the DM yield (Bélanger & Gastal, 2000).

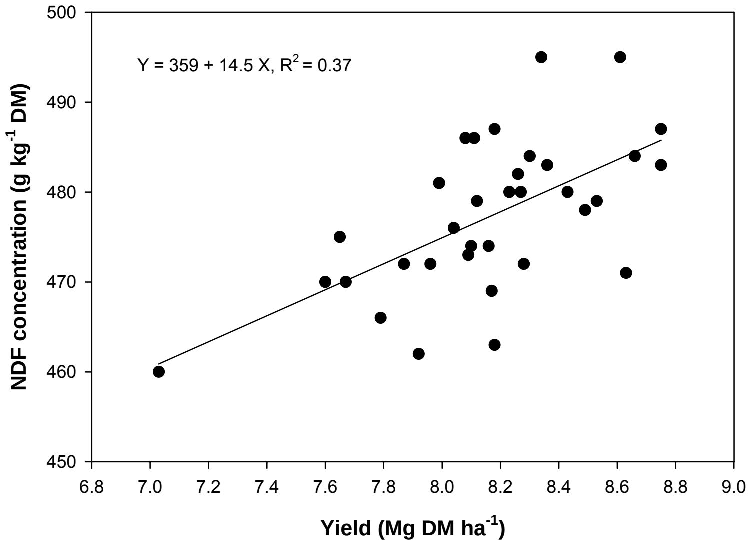

Figure 3. The NDF concentration of 34 timothy cultivars grown at one site in eastern Canada as a function of forage DM yield (adapted from Kunelius *et al*. 2003). Values are averages of three years and four harvests per year.

of this structural component. Selecting for reduced fibre concentration might be successful but this approach can reduce forage yield since fibres represent more than 50% of forage DM in timothy. An alternative is to increase the digestibility of the fibre. In forage grasses, the fibre is composed primarily of cell-wall cellulose, hemicellulose, and lignin (ADL). Since the three fibre components have different digestibility, a decrease in less digestible fibre components or an increase in more digestible fibre components should increase forage DM digestibility.

Selection based on fibre traits may make it possible to improve forage digestibility while maintaining plant biomass. A breeding study showed that phenotypic selection based on the ratio of concentrations of ADL to cellulose could be used to improve timothy DM digestibility without reducing plant biomass (Table 2; Claessens *et al*. 2004, 2005a) or affecting plant morphology (Claessens *et al*. 2005b). The observed changes in overall herbage DM digestibility were attributed primarily to modification of stem digestibility. The importance of stem digestibility was also observed in a previous study (Bélanger *et al*. 2004). These results, along with those obtained on genotypes (Table 2; Brégard *et al*. 2001), confirm the possibility of improving timothy DM digestibility while maintaining forage yield.

Protein quality

Forage proteins are often poorly used by ruminants because they are extensively degraded during silage fermentation and in the rumen. Extensive degradation of proteins results in poor forage N utilization by ruminants and substantial N losses to the environment. Nitrogen fertilization of timothy increases forage yield and N concentration but little attention has been paid to the quality and feeding value of the protein in the herbage. The Cornell Net Carbohydrate and Protein System (Sniffen *et al*. 1992; Licitra *et al*. 1996) has been extensively used to characterize protein degradation in forages. In this system, fraction A is non-protein N, B is true protein, and C is unavailable true protein. Fraction B is further divided into three fractions (B1, B2, and B3) that have decreasing rates of ruminal degradation. Fractions A and B1 are soluble and readily degradable.

Table 2. Values for NDF concentration, *in vitro* true digestibility (IVTD), *in vitro* NDF digestibility (NDFD), and DM yield of timothy from a study (Brégard *et al.* 2001) with genotypes under controlled conditions and from a field study (Claessens *et al.* 2004, 2005a) with genotypes and populations chosen and selected from the ratio of lignin (ADL) to cellulose (CEL).

		NDF g kg^{-1} DM	IVTD g kg^{-1} DM	NDFD g kg^{-1} NDF	DM yield g $plant^{-1}$
Brégard *et al.* (2001)					
9 genotypes + cv. Champ					
	Non-limiting N	564-578	822-858	695-749	3.1-4.0
	Limiting N	527-594	816-880	695-778	1.1-1.5
Claessens *et al.* (2004, 2005a)					
Genotypes					
	Low ADL/CEL	590	853	763	205
	High ADL/CEL	593	839	742	163
Populations					
	Low ADL/CEL	568	857	749	162
	High ADL/CEL	582	830	717	152

With increasing N fertilization of 35 early-maturing timothy genotypes, concentrations of total N (TN) and A+B1 protein fractions increased by 27 and 6%, whereas concentrations of B2 and C protein fractions decreased by 5 and 12%, respectively (Figure 2d; Michaud *et al.* 2003). The concentration of B3 protein fraction and DM yield were not affected by N fertilization. The N fertilization had therefore a negative effect on timothy protein quality; it increased the soluble protein fraction and decreased the protein fraction that has an intermediate rate of degradation.

Timothy genotypes differed significantly for TN and protein fractions A+B1, B3 and C, and DM yield (Michaud *et al.* 2003). Protein fractions A+B1, B2, and B3 were not correlated with DM yield and TN. Genotypes combining high DM yield, high B2 and B3 fractions, and a low A+B1 protein fraction can be identified. This, combined with earlier work (Michaud *et al.* 1998), suggests that genetic variability exists for the relationship between DM yield, N concentration, and protein quality as defined by the protein fractions. This leads to the possibility of developing high yielding timothy cultivars with an increased N concentration and protein quality. Selection for a high N concentration with no consideration for DM yield, however, can result in lower DM yield (Brégard *et al.* 2000).

Dietary cation-anion difference

The mineral composition of forages plays an important role in the development of metabolic disorders such as milk fever and acidosis. Milk fever, a severe hypocalcaemia, is an economically important metabolic disease (Goff &Horst 2003) occurring at or near parturition, especially in high producing dairy cows. It affects 5 to 7 % of dairy cows in the USA (Sanchez 1999). In Australia, 1.6 to 5.4 % of dairy cows are affected and, in some years, the incidence of hypocalcaemia may be more than 20 % in individual herds (McNeill *et al.* 2002). At a sub-clinical level, hypocalcaemia can affect 66% of multiparous cows in the USA and 33 to 40 % in Australia and New-Zealand. The acidosis in dairy cows has also been linked to the mineral composition of the diet.

The concept of the dietary cation-anion difference (DCAD) has primarily been used in the context of preventing milk fever. Dry dairy cows fed forages with a high DCAD are more likely to develop hypocalcaemia. Forages produced on intensive dairy farms often have a high DCAD. Although several equations have been proposed to calculate the DCAD of a ration, an equation including two cations and two anions (Ender *et al.* 1971) is widely used:

$$DCAD = [(K^+ + Na^+) - (Cl^- + S^{2-})]$$

Forage-based rations with a low DCAD should therefore be fed to dairy cows 2 to 4 wk prepartum to prevent hypocalcaemia or milk fever.

Timothy has been identified as a potentially good grass for dry dairy cows. It has a lower DCAD than other cool-season grass species because of its lower K concentration (Tremblay *et al*. 2006). Timothy is therefore the best suited cool-season grass for producing forages fed to dry cows in the weeks preceding calving. The DCAD of timothy decreases with advancing development (Figure 1c); this reduction is attributed to a decrease in K concentration and a slight increase in Cl concentration (Pelletier *et al*. 2006). Nitrogen fertilization has a limited effect of timothy DCAD (Figure 2c). Hence, harvesting timothy at late heading or later, with an appropriate N fertilization to ensure adequate yield, is an option to produce forages with a low DCAD (Figure 4).

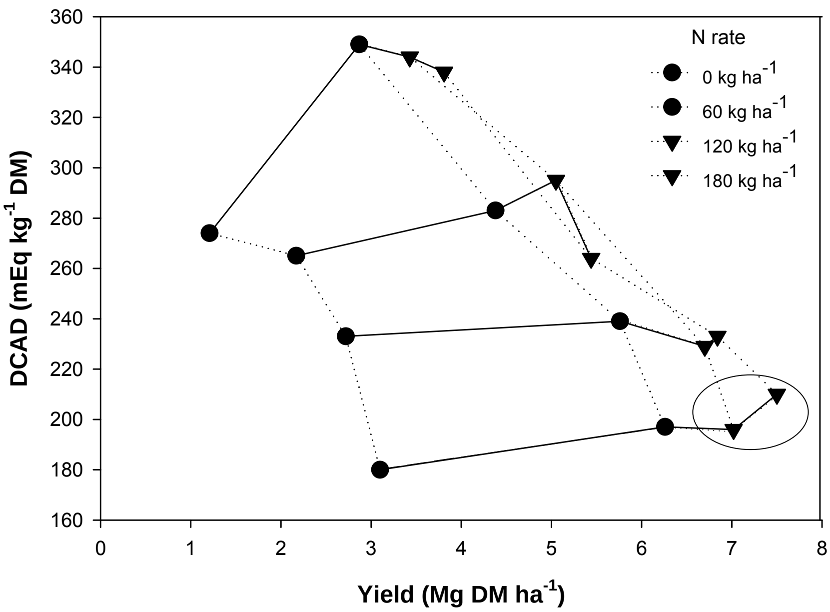

Figure 4. Relationship between the dietary cation-anion balance (DCAD) and DM yield of timothy grown under four levels of N application and harvested on four sampling dates during the primary spring growth at one site in eastern Canada (adapted from Pelletier *et al.* 2006). Dotted lines, data from one N rate; solid lines, data from one sampling date; circle represents a desired situation for the production of forages for dry cows (high yield and low DCAD).

Water soluble carbohydrates

Crop composition at harvest affects the ensiling process and the resulting silage quality. Water soluble carbohydrates (WSC) are the main source of fermentable substrates during ensiling and along with buffering capacity (BC) influence the ensiling process. The BC of herbage is its ability to resist a change in pH. The effect of N fertilizer application on timothy forage yield and nutritive value is well documented but less research has been conducted on their impact on timothy silage quality. In a study conducted at two sites in eastern Canada, higher rates of N-fertilizer application decreased the concentration of WSC, increased the buffering capacity and nitrate concentration, and decreased the ratio of WSC to BC, primarily in the early stages of development (Figure 2b; Tremblay *et al*. 2005). The ensiling properties are therefore less favourable when high rates of N fertilizer are applied. Silage quality is reduced by increased N-fertilizer application, primarily at the early developmental stages, and this can be attributed to a reduction in WSC concentration and an increase in the buffering capacity of the forage.

The changes in the concentration of WSC with advancing maturity is the subject of conflicting reports and inconsistent results, partly because of the confounding effect of climatic conditions on or near the sampling dates. Furthermore, few studies on changes in the WSC concentration with advancing maturity have been conducted on timothy. In a study where timothy was harvested at four stages of development from stem elongation to early flowering during the primary spring growth, the WSC concentration and the buffering capacity of timothy tended to decrease with advancing maturity (Figure 1b; Tremblay *et al*. 2005). The decrease in the buffering capacity could be related to the concomitant decrease in N concentration.

Fatty acid concentration

Maximizing α-linolenic acid (C18:3) in milk and dairy products is likely to benefit human nutrition and health. The C18:3 concentration of milk fat is influenced by the forage C18:3 concentration (Hebeisen *et al*. 1993). Consequently, agronomic practices affecting the fatty acid (FA) composition and concentration of forages could impact the C18:3 content of milk. Forages can provide a significant quantity of fatty acids to ruminants if they represent a high proportion of diets. The FA concentration in forages depends on many factors, including growth stage (Bauchart *et al*. 1984; Dewhurst *et al.* 2001), conservation method (Lough & Anderson 1973; Yang & Fujita 1997), N fertilization (Jarrige *et al*. 1995) as well as wilting, shading, and silage additives (Dewhurst & King 1998). In timothy, however, little is known about the factors affecting its FA concentration.

Timothy had a higher C18:2 concentration than other forage grasses but a lower C18:3 concentration (Dewhurst *et* al. 2001; Boufaïed *et al.* 2003). Concentrations of C18:2, C18:3, and total FA in timothy decreased, respectively, by 16, 31, and 23% between stem elongation and early flowering (Figure 1c; Boufaïed *et al*. 2003a). Nitrogen fertilization caused an increase of 12% of C18:2, 40% of C18:3, and 26% of total FA concentrations (Figure 2c). Concentrations of C18:2, C18:3, and total FA in timothy are therefore greatest at an early stage of development and with N fertilization. Wilting and drying decreased timothy C:18:2, C18:3, and total FA concentrations but it increased the ruminal bypass of C18:3 (Boufaïed *et al*. 2003b). Concentrations of C18:2, C18:3, and total FA were higher in summer regrowth than in spring growth. Polyunsaturated FA concentrations in forages can be increased by harvesting timothy at an early stage of development, by increasing N fertilization, and by conserving the forage as dry hay. Further research, however, is required to determine the impact of increased timothy C18:3 concentration on the milk C18:3 content.

Conclusions

The negative relationship between nutritive value and forage DM yield is well documented (Bélanger *et al*. 2001) and it has been central to our research efforts over the last 10 years. From this relationship, it is often inferred that any factors increasing DM yield will most likely result in a decrease in nutritive value. Conversely, factors decreasing DM yield may result in an increased nutritive value. Although this negative relationship applies to several parameters of nutritive value (Figures. 1, 2, and 3) and agronomic practices, it does not apply to all. For instance, in the case of the dietary cation-anion difference, high forage DM yield is associated with a low DCAD, which is favourable for dry cows (Figure 4). Another example is the positive effect of N fertilization on DM yield with no negative effect of DM digestibility; this illustrates the possibility of dissociating DM yield and nutritive value through management practices.

This negative relationship between parameters of nutritive value and DM yield also suggests that cultivars with greater forage DM yield may have a lower nutritive value (Figure 3). The improvement of both DM yield and nutritive value requires the identification of genotypes exhibiting a weaker negative relationship between DM yield and nutritive value. Genotypes with high yield potential and high nutritive value have been identified (Table 2; Brégard *et al*. 2001, Claessens *et al*. 2005a,b). However, there are still no timothy cultivars showing improvement in both forage yield and nutritive value and research efforts are still needed to incorporate this genetic variability into commercial cultivars.

In a previous review paper (Bélanger *et al*. 2001), we discussed the nutritive value in relation to the accumulation of forage yield, and by considering that the forage was made of two components: metabolic and structural. Our recent studies confirm that improvements in the digestibility of the structural component, either taken as the true stems or the NDF, has the potential of improving forage DM digestibility with no negative impact on DM yield. Along with the more traditional production-oriented DM yield and digestibility, other parameters of nutritive value should also be considered in the context of improving human, animal, and environmental health.

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Timothy and timothy mixtures as a pasture crop

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Introduction

The objectives of grazing management are to supply herbage of high nutritive value over the growing season at low cost, to ensure efficient utilization of herbage while maintaining acceptable levels of animal performance and to maintain sward productivity. A grass species that is well suited for grazing must be suitable for different grazing conditions, have good regrowth ability, an even dry matter production and high nutritive value, mostly through a high proportion of leaves throughout the grazing season. Under a Nordic climate the herbage has to be winter hardy. Therefore, timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.) are more commonly used in Nordic countries for grazing purposes since the winter hardiness of perennial ryegrass (*Lolium perenne* L.) is weak.

This paper focuses on timothy and timothy-dominated mixtures for grazing. Whereas there is sound knowledge concerning timothy for silage use (Höglind *et al.* 2005), there is clearly less knowledge for pasture use. Therefore, most of the results originate from a series of experiments conducted in 1997 - 2005 in Central Finland, though some other Nordic sources are used as well. The basic principles of growth and utilization can also be applied elsewhere at northern latitudes.

Leaf growth and senescence

The growth processes, such as leaf appearance rate (LAR), leaf elongation rate (LER), and leaf life span (LLS) of timothy and meadow fescue differ from each other in the generative growth phase in May - June. The difference between species is smaller in the vegetative growth phase in July - August. Overall, timothy is characterised by higher tissue turnover rates (Table 1).

Table 1. Effect of species and season on leaf appearance rate (LAR), leaf lamina elongation rate per degree day ($LER_{gross}DD$), leaf life span in degree days (LLSDD) and leaf lamina area. T = timothy, MF = meadow fescue. (Reproduced from Virkajärvi & Järvenranta 2001).

	May- June		July-August			P-values		
	T	MF	T	MF	SEM[1]	species	season	species x season
LAR (leaves d^{-1})	0.130	0.083	0.126	0.070	0.0065	<0.001	0.118	0.43
$LER_{gross}DD$ (mm $tiller^{-1}$ $°C^{-1}$ d^{-1})	2.24	1.30	1.39	0.94	0.124	<0.001	<0.001	0.021
LLSDD	389	414	465	633	20.0	<0.001	<0.001	<0.001
Leaf area (cm^2 $tiller^{-1}$)	52.2	17.8	34.5	28.8	5.39	<0.001	0.470	0.003

[1] SEM = standard error of the mean

The net leaf elongation rate (LER_{net}) is a result of the LER_{gross} and leaf senescence rate (LSR). The mean LER_{net} was found to be only 44 – 60 % of LER_{gross}, and therefore LER_{net} is clearly a more relevant descriptor in determining the leaf area development or growth of a tiller than LER_{gross}. Due to differences between the generative and vegetative growth phases and rapid changes in climatic variables 'steady state growth' seldom occurs in Finnish swards.

Tiller dynamics

In general the tiller density of timothy seems to be almost similar to that of meadow fescue. The tiller population density (all tillers) in timothy - meadow fescue pastures ranged from 2360 to 5280 tillers m^{-2} (Virkajärvi 2004). However, during the first part of the summer the proportion of vegetative tillers is clearly lower in timothy than in meadow fescue. As the population density of all tillers is similar again in August, timothy must produce more new tillers between June and August in order to compensate for the higher proportion of cut generative tillers. The ability of timothy and meadow fescue to compensate for reduced tiller size (caused by close defoliation) by increasing tiller density is less than that of perennial ryegrass (Virkajärvi 2004). This holds at least under long day conditions, which are known to increase tiller size and height and reduce tiller formation of timothy (Heide *et al.* 1985).

Apex development and stem formation

The growth process of a sward is crucially dependent on whether tillers are in a generative stage or in a vegetative stage. The relative growth rates for herbage mass (HM) production of vernalized tillers is 30 – 50 % higher than that for unvernalized tillers (e.g. Bartholomew & Chestnutt 1978). On the other hand, tillers that have elevated their apex in the grazing horizon will die with defoliation. The regrowth rate will be reduced and also the use of C-reserves will be less efficient compared to tillers that have an apex below the grazing horizon (Richards & Caldwell 1985).

In both timothy and meadow fescue the primary tillers switch to the generative growth phase in early May and soon after that the apex is elevated as stem formation begins. The switch is strongly related to the temperature sum (base T = 0°C). The elevation rate of the apex in primary tillers is a maximum of 25 - 30 mm per day during the most rapid development. The axillary tillers start to elongate a little later. Timothy needs only a single long day induction for flowering, whereas most temperate, perennial grass species need short days or low temperature for primary induction and then long days for secondary induction (Heide 1994). Therefore also the axillary tillers of timothy may have floral induction under long day conditions. It seems to be a common phenomenon that a part of vegetative tillers of timothy start to elongate and produce nodes before the apex has switched to the generative stage. Due to both of these phenomena, a high proportion of timothy tillers have stem formation in the early part of the summer (0 - 0.5, Bonesmo 1999; 0 – 0.82, Virkajärvi *et al.* 2003; 0.44 – 0.65; Virkajärvi 2003). This is one reason for the very pronounced peak in DM production of timothy in mid-June, 120 – 180 kg DM ha^{-1} d^{-1} (measured in a grazing simulation of 4 week cycles). In contrast, the production is very variable in July (30 – 100 kg DM ha^{-1} d^{-1}) and falls under 50 kg DM ha^{-1} d^{-1} in mid-August. These conditions must be taken into account in pasture allocation.

In a series of experiments in Finland it was found that in the generative stage (June) the regrowth rate of a timothy or timothy-dominated pasture was well explained by the amount of vegetative tillers per m^2. The overriding importance of surviving tillers has also been reported for cuts on early and late silage stages (Höglind *et al.* 2005). The other factors, such as post grazing leaf area index (LAI), water soluble carbohydrates (WSC), degree of polymerization of fructans or nitrogen content of the stubble had only a weak effect or no effect at all (Virkajärvi 2004). Using expolinear growth equations Bonesmo (1999) showed that the proportion of non-elongated tillers was the most important factor for both timothy and meadow fescue for maximum growth rate. WSC was important only for the initial growth rate. In general, meadow fescue has a better regrowth ability (7 - 10 % in DM) than timothy, especially under low soil moisture (Virkajärvi 2003) and its regrowth ability is less sensitive to the phenological stage than that of timothy (Bonesmo 1999). Therefore a mixture containing both of the species seems a good alternative.

In addition to DM production, the stem formation process affects the nutritive value of the yield. In the early stages of stem formation the stem tissue has a high digestibility. Later, stem digestibility decreases rapidly. In Finnish grazing experiments the negative effect of stem tissue occurs when the canopy height has reached a height of 40 cm. The latest development stage suitable for grazing is when the flag leaves become visible or are fully expanded. When the majority of tillers reach the 'boot swollen' stage, the sward is too mature for grazing and a high proportion (up to 50 %) of HM will be lost due to rejection and trampling (Virkajärvi 2004).

Animal production on timothy-dominated pastures

The growth processes described above lead to sward structure that differs from that of perennial ryegrass at more southern latitudes. Timothy-dominated pastures typically have a lower tiller density, lower HM bulk density, individual tillers are large and tall, stem formations occurs commonly till mid-summer, and consequently the proportion of leaves is low (Table 2). Together with the chemical composition of HM all these factors affect the animal's ability to have a high intake rate of highly digestible dry matter. A farmer can influence these parameters and consequently adjust animal intake by grazing management. The most important management options are herbage allowance, (HA; kg DM cow^{-1} day^{-1}), timing of turnout and grazing system. Fertilization levels and concentrate use are beyond the scope of this paper.

Table 2. Sward structure of timothy-dominated pastures and typical perennial ryegrass pastures (timothy from Virkajärvi 2004; ryegrass from Mayne and Wright 1988, McGilloway *et al.* 1999, Casey & Brereton 1999, Parga *et al.* 2000).

	Timothy	Perennial ryegrass
Herbage mass, kg ha^{-1} DM	2000 - 3500	1700 - 5900
Tiller density, tillers m^{-2}	1700 - 5300	5000 - 15000
Pre grazing sward height, cm	25 - 40	12 - 24
Proportion of leaves in live material	0.46 - 0.68	0.50 - 0.87
Bulk density kg DM m^{-3}	0.68 - 0.92	1.7 - 5.5
Organic matter digestibility, g kg^{-1} OM	767 - 806	750 - 820

The general relationship between HA and milk yield increment (0.16 kg energy corrected milk kg^{-1} DM; Virkajärvi *et al.* 2002) seems to be similar for timothy-dominated swards under Nordic conditions to perennial ryegrass swards under more temperate conditions. This means that the ease by which a cow harvests the energy is similar despite the differences in sward structure. In addition to the DM allowance, the relative herbage allowance (RHA) also takes into account the animal energy requirement and digestibility of grass (RHA = digestible energy allowance /energy requirement). It was found that the relationship between RHA and HM utilization is fairly uniform over a wide range of HA experiments (see Virkajärvi 2004 and references therein). Relative HA of 1.65 – 1.70 (HM > 3 cm) seems to be a good compromise between the production per animal and production per land area on timothy-dominated swards.

The adjustment of HA leads to different sward heights. In shorter swards the effect of bulk density on herbage intake of the animals increases but in tall swards the effect of sward height is the most important condition (McGilloway *et al.* 1999). Therefore in Nordic, tall and sparse timothy-dominated pastures it is important to achieve high pre-grazing heights in order to have high intake rates. This leads to long grazing intervals depending on the regrowth rate. On the other hand, the utilization of swards higher than 40 cm is low, which is largely explained by the low OMD but also by increased stem rigidity. Presumably the increased stem rigiditycauses lower intake per bite due to reduced bite area. In addition, increased stem rigidity may cause marked losses due to trampling of the canopy. A grazing height of 9 – 10 cm can be recommended for dairy cattle producing 25 – 40 kg energy corrected milk per day (Virkajärvi *et al.* 2002, 2003).

Early turnout slightly restricts HM production, which is largely explained by the stem formation process. On the other hand, lower HM production with early turnout is counterbalanced by a higher nutritive value of the grass. With only a few days of delay in turnout date, the pasture growth type and hence its management can change dramatically (Virkajärvi *et al.* 2003).

One solution to having an efficient but easy to manage grazing system is part-time grazing. In a comparison with indoor feeding with silage, the part-time grazing gave higher milk yields per cow, mainly due to the higher D value of pasture compared to silage (Table 3). Economic analysis showed that full-time grazing gave the highest economic return and full-time indoor feeding the poorest, while part-time grazing resulted in intermediate returns (difference between milk production revenue and feeding costs; Seppälä *et al.* 2006). However, part-time grazing is easy to manage under variable climatic conditions due to its flexibility.

Table 3. Part-time grazing: hours spent on pasture, D value of silage and pasture grass, and energy corrected milk yield (ECM) in two experiments (adapted from Sairanen *et al.* 2006).

				P value	
	Exp.[2]	Indoor	Grazing	Diet	diet x month
Indoor (silage)/ , outdoor (grass), h d^{-1}	1	12	12	-	-
	2	18	6	-	-
D value, g DOM kg^{-1} DM, (silage/grass)[1]	1	684	729	-	-
	2	662	715	-	-
ECM, kg cow^{-1} d^{-1}	1	27.7	30.8	< 0.001	< 0.001
	2	26.8	27.5	Ns	< 0.01

[1]Silage for both groups, pasture grass only for the grazing group.
[2]Exp 1 = night time grazing; Exp 2 = day time grazing

Despite the fact that timothy is not a pasture grass, based on its growth processes and peaked HM production with slow regrowth, especially in dry conditions, it counterbalances these weaknesses by having a high nutritive value. Timothy is commonly stated to have high palatability, at least compared to meadow fescue and cocksfoot (*Dactylis glomerata* L.), although the magnitude or consequences have not been sufficiently quantified. Compared with perennial ryegrass, timothy has produced 14 % higher daily LW gains for lambs (Davies & Morgan 1982) and a high milk solids yield of dairy cows (Thom *et al.* 1998; timothy – perennial ryegrass mixture), results that provide other evidence for the productivity of timothy pastures when measured through animal production. However, the reasons for advantages measured, for example, in New Zealand may be different in Scandinavia (see, e.g. Charlton & Stewart 2000).

Conclusions

Despite the relatively low tolerance against grazing and peaked DM production, timothy can be used efficiently for grazing, especially in mixtures with meadow fescue. The growth processes lead to specific management options, e.g. early turnout, high pre-grazing sward heights, flexible grazing systems with large variation in rotation length, and possibly part-time grazing.

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Breeding goals and possibilities in future timothy breeding

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Introduction

In the genus *Phleum* at least 10 species have been recognized (Cai & Bullen 1994). The only cultivated timothy is *Phleum pratense* L., although the diploid species *P. bertolonii* DC. is cultivated in some countries (Cai *et al.* 2003). Due to its adaptation to the cool and relatively humid northern climate, timothy is an important forage grass that is widely grown in the cool, temperate regions of the world, including Europe, North America and Asia. In the northern part of the Nordic countries it is the most important forage grass. The species is well adapted to the winter conditions and possess good quality as fodder.

The cultivation of timothy started first in North America. The early history is unclear, but there are references to the cultivation of timothy in the early 1700's. Early agronomists referred to it as Herd grass after John Herd. He reportedly found it about 1711 growing wild along the Piscataqua River near Portsmouth, N.H. The name timothy probably came from Timothy Hansson, who played an important role in promoting the use of this grass in Maryland, North Carolina and Massachusetts (Powell & Hanson 1973). In 1807 timothy was the most important forage grass in the USA and it remained in that important position for the next hundred years (USDA 1937). From North America the cultivation of timothy spread to England in the 1760's and from England to the other European countries. However, in Sweden timothy was reportedly cultivated under the name "Ängskämpe" before seed had arrived in North America in the early 1700's. In Norway the cultivation of timothy probably started in the late 1700's.

The species

From the point of view of breeding , timothy is a complicated species with its hexaploid set of chromosomes (2n=6x=42). The genomic constitution of timothy (autotetraploid vs. allotetraploid) is unclear (Cai *et al.* 2003). Most studies since the 1940's have supported the hypothesis that timothy is an autotetraploid (Opsahl 1964). Later Cai & Bullen (1991) suggested that timothy consisted of two genomes, A and B. The genomic constitution of timothy would be AAAABB, with the A-genome originating from a tetraploid form of *P. alpinum* and the B-genome from the diploid *P. nodosum (bertolonii).* Cai & Bullen (1994) found strong support for the allotetraploid nature of cultivated timothy by isolation of genome-specific DNA sequences from diploid *P. nodosum* and *P. alpinum.* They found a close relationship between timothy and these two diploid species. Cai & Bullen (1994) also demonstrated that there was little divergence between the genomes of *P. alpinum* and *P. nodosum*. In a study by Cai *et al.* (2003), the timothy showed some autohexaploid properties. They found up to six multiple alleles in hexaploid clones, while in the diploid species *P. nodosum* and the tetraploid species *P. alpinum*, the maximum number of multiple alleles did not exceed two and four, respectively. At the moment the genetic constitution in timothy is not completely resolved.

A positive factor for plant breeding is that timothy has no winter requirement for flowering and requires only a regular long day induction to flower (Heide 1994).

Genetic resources

The basic material in a breeding program is important for the outcome of the breeding effort. Breeding new cultivars of timothy relies on broad genetic variation. We need variation for important characters like yield, resistance to pathogens, frost tolerance, forage quality, and seed production. There are several sources of variations in these characters. We can find a useful variation in local populations, local cultivars and commercial cultivars.

Nordic material

The breeding history in forages is relatively short. The cultivars used today are therefore not very different from the old local cultivars and local populations that they have been developed from. Only 50-60 years ago there existed a large number of local cultivars in the Nordic countries. These local cultivars were adapted to the local climatic and soil conditions by many generations of natural selection. The local cultivars have probably interesting characters that can be used in our breeding programs. In Finland a good number of these local cultivars were kept until they were stored in the Nordic Genebank (NGB). In Norway and Sweden, however, most of them were lost before the values of these old local cultivars were realized.

In the 1970's several collection trips were carried out in the Nordic countries in order to collect the remnants of these old local cultivars that we hoped still existed in old pastures and meadows and to collect other local populations. Collections have been done in most parts of the Nordic countries, but the geographical coverage of NGB's timothy collection is not yet complete. Uncollected areas comprise almost all of central Sweden, parts of the provinces Kainuu and North Ostrobothnia in Finland, and the Danish islands of Fyn and Sjælland, as well as on many small islands.

In the Nordic countries NGB is responsible for the storage and maintenance of Nordic plant genetic resources. Today NGB has a collection of 596 accessions of timothy. This collection consists of bred cultivars, local cultivars, breeding material and locally collected populations (Table 1).

Table 1. Accepted accessions of timothy stored in the Nordic Genebank.

Country	Cultivars	Local cultivars	Breed material	Local populations	Total
Denmark	10			11	21
Finland	8	118	1	43	170
Iceland	1	1			2
Norway	5	1	4	238	248
Sweden	15	2		138	155
Total	39	122	5	430	596

The largest part of this collection is locally sampled populations with a total of 430 accessions. Local cultivars have almost solely been preserved in Finland. Less than 10% of the accessions are bred cultivars. The largest number of accessions comes from Norway.

Characterization and evaluation

Part of this collection has been characterized for morphological traits in a Nordic NGB project. The characterization was done on the accession basis not on single plants within the accession. A large variability existed for most characters studied (Nordic Gene Bank, http://www.ngb.se). The value and genetic structure of this collection has not yet been studied based on modern molecular tools. Such types of study have been planned in a Nordic project application to NKJ. For plant breeding such information would be of great value since it would make the collection more accessible for plant breeders who will be able to improve specific traits, to target their work better and to develop new varieties more efficiently.

A total of 81 of the Norwegian accessions stored in the Nordic Genebank were evaluated in Norway 1984-1987. (Marum 1988 & Solberg *et al.* 1990). Great variation existed in the characters tested (Table 2).

Table 2. The distribution of *per* cent ground cover in the spring of the third harvest year in 81 Norwegian timothy accesions stored in the Nordic Genebank.

Ground cover %	No. of accessions	Reference cultivars
15 – 20	3	Polka
20 – 25	5	
25 – 30	3	
30 – 35	5	
35 – 40	8	
40 – 45	11	Grindstad
45 – 50	10	
50 – 55	12	
55 – 60	6	
60 – 65	8	
65 – 70	4	Bodin
70 – 75	2	
75 – 80	4	Engmo

Per cent ground cover in the spring is a good indicator of winter hardiness. There was a clear relationship between the climate where an accessions was collected or bred and winter hardiness. The best material from this testing has been used further in the Norwegian breeding programme.

Another very important source of breeding material is good commercial cultivars. Most forage cultivars are very heterogeneous, and large variation exists within the cultivars. This variation can be exploited in our breeding programs.

Exotic material

Gene banks in other European countries also have large collections of timothy (Table 3).

Table 3. Number of timothy accessions stored in European countries.

Country	Number of accessions
Belgium	5
Bulgaria	9
Czech Republic	108
Germany	990
France	46
United Kingdom	182
Hungary	102
Ireland	32
Italy	2
Lithuania	18
Poland	2740
Nordic countries	596
Romania	32
Slovakia	83
Slovenia	40
Turkey	5
Total	4990

This information is taken from the ECP/GR's central European *Phleum* database (European Co-operative Programme for Crop Genetic Resources Networks (ECP/GR). The relatively large *Phleum* collection held at the Vavilov Institute in St. Petersburg in Russia is not yet included in this database. More than 5000 accessions of *Phleum* exist in Europe and more than half of them are stored in Poland.

Breeding goals

The following goals for timothy breeding were proposed by a group planning forage breeding in Norway (Larsen *et al.* 2003):

- High dry matter (DM) yield.
- Good distribution of DM production over the growth season with low percentage of straw after first cut.
- Cultivars for intensive use and pasture, tolerating frequent cutting and grassing.
- High fodder quality.
- Good winter hardiness and persistence.
- Resistance to disease, especially low temperature fungi.
- High seed production.

Especially for organic and low input production N use efficiency, quick establishment and good competition with weeds could be added to these goals.

DM yield

Substantial increases in DM yield through breeding have been difficult to achieve. Bélanger *et al.* (2001) indicated that yield potential continues to be a primary selection criterion in timothy breeding; however, in the public forage cultivar testing system of Ontario the highest-yielding cultivar exceeded the check, Climax, licensed in 1947, by only 9 percent. This can also be demonstrated from intensive variety testing in Norway where the old local variety ‘Grindstad’ continues to be the highest yielding in all areas where special winter hardiness is not required. Adaptation to growth and management conditions has been more successful and new cultivars are proposed for listing (Molteberg & Enger 2006).

Three cycles of recurrent restricted phenotypic selection were not effective in improving the forage yield of timothy (Shateryan *et al.* 1995). After four years of sward and space plant evaluation there were no significant differences in forage yield among the different selection cycles. The spaced plant showed a trend to shorter and smaller plants in timothy over selection cycles. Plant persistence and maturity were not affected. In a co-operative Nordic breeding program in timothy for the northern areas of Scandinavia, 60 half-sib families with parents from the national breeding programs were tested at five regional sites under sward conditions for three years. Significant differences in yield between families were found, with significant differences for sites and years. Clones with superior offspring and high yield stability over sites and years were selected for composing two synthetic varieties (Helgadottir *et al.* 1995). Test results of the new cultivars showed them to be not very different from commercially used varieties. However, the new candidate cultivars competed best in the northernmost areas and the new cultivar ‘Snorri’ was registered.

Distribution of DM yield

Varieties grown in northern areas are highly adapted to photoperiod with a production peek during the longest days (Foss 1968). More production in spring and late summer is wanted from the farmers, especially for spring and late summer grassing (Larsen *et al.* 2002).

Early cutting will influence the regrowth and production later in the season. Van Oijen *et al.* (2005) observed that cutting at early heading tended to be followed by a longer lag phase than cutting at anthesis. This was partly dependent on carbohydrate concentration, plant phonological stage and sprouting of new tillers from cut generative tillers.

Winter hardiness and persistence

For a perennial species good winter hardiness is essential and the importance increases from south to north and from coast to inland. The plants must tolerate and be resistant to both physical, physiological and biotic stress factors (Larsen 1994), and have sufficient energy store for surviving an unproductive winter. Considerable genetic differences in adaptation to wintering conditions exist in timothy. Andersen (1960) showed northern varieties to accumulate a higher amount of sugars during autumn than the more southern-adapted varieties. Comparing three timothy varieties with different adaptations during a wintering period showed the most northern adapted variety 'Engmo' to have the highest content of water soluble carbohydrates (WSC) and the slowest decrease in WSC content from mid- to late winter. Consequently, 'Engmo' kept hardening, measured as freezing tolerance, during late winter better than the south Norwegian 'Grindstad' and especially a variety from Wales (Larsen 1994). Thorsteinsson *et al.* (2002) showed that at reduced growth temperatures the northern 'Vega' had a significantly higher total carbohydrate and fructan content than 'Climax', suggesting possible differences in genetic adaptation to cool growth temperatures.

Varieties adapted to hard wintering conditions reduce leaf growth in late summer and autumn and store assimilation products in plant base and roots. Consequently, such varieties will have low forage production in the second and third cut, which can be illustrated from official variety testing (Molteberg & Enger 2006). A balance between productivity and hardiness must be practised in the breeding work.

High fodder quality

The quality of timothy as feed for ruminants is essential and must have high priority in future breeding work. Belanger *et al.* (2001) assumed that forage yield is the result of two components, metabolic and structural. With increased forage yield the proportion of the metabolic component decreases and the nutritive value of timothy is reduced. A cultivar has both an indirect and a direct effect on the nutritive value through increased yield and change in the proportion of the metabolic and structural components. Therefore, through plant breeding the yield and nutritive values could be dissociated and nutritive value improved while maintaining yield. It is possible to break the linkage between high DM yield and declining nutritive value parameters and select for high yielding genotypes with superior forage nutritive value.

Stem growth is important for yield increase in timothy, but a high amount of stems will decrease quality. The possibility of selecting genotypes with a high yield and high leaf weight ratio (LWR) was indicated by variability in the relationship between forage dry matter (FDM) and LWR (Bregard *et al.* 2001).

However, the quality of the fibre in the stems is of great importance. Kobayashi *et al.* (2005) found the neutral-detergent fibre (NDF) vs. DM yield relationship in timothy to be expressed as a positive linear regression across different cuts, only slightly affected by cropping year. The regression lines differed between genotypes, indicating a lower NDF and acid-detergent fibre (ADF) concentration in some genotypes across varying years. Such genotypes could be useful as parental material to improve forage quality without reducing DM yield.

Populations selected for low values of acid-detergent lignin (ADL) / cellulose (CEL) showed reduced ADL and NDF concentrations in stems and increased the in vitro true digestibility (IVTD) of stems but had no consistent direct effects on plant morphology or leaf characteristics. Stems of low selected ADL/CEL populations had lower ADL and NDF concentrations and IVTD value than those of the high ADL/CEL group of genotypes. Stems of the low-ADL/CEL populations had lower ADL and NDF concentrations and a higher IVTD value than contrasting populations. The changes in overall herbage DM digestibility could be attributed manly to modification of stem digestibility (Claessens *et al.* 2005).

Belanger *et al.* (2004) confirmed the presence of genetic variability for leaf and stem nutritive value (IVTD, IVCWD and NDF of stem) in timothy both under limiting and non-limiting N conditions.

The indigestible part of NDF (INDF) varies in plant materials during the identical development stage and may be an important selection criterion for increased digestibility. INDF is an important parameter in the new Nordic system for evaluating quality of fodder (Volden 2006).

Tolerate high harvest intensity and grazing

Because of animal welfare and the economy, grazing will be more important in the future. Timothy as a species is not well suited for grazing, and not much work has been done to adapt cultivars for this use. However, timothy is and will be an important part of pasture because of its good palatability and production.

Testing 34 timothy cultivars under grazing in Eastern Canada Kunelius *et al.* (2003) obtained significant differences in yield and relative yield persistence, and tiller densities over a period of 3 years. The rate of change in fibre concentration from early to late grazing also varied among cultivars.

Cheplick & Chui (2001) studied half-sib families of timothy grown in pots, without and with competition from *Lolium perenne*, and observed genetic variation for competitive ability and the ability to regrow rapidly after defoliation, dependent on storage in stem base.

Disease resistance – low temperature fungi

Even timothy is attacked by some leaf spot fungi such as *Cladosporium phlei* and such insects as leaf-mining flies and timothy fly; an attack of low temperature fungi during wintering is the most important. Compared to the second most used grass in northern areas, meadow fescue (*Festuca pratensis* Huds.), timothy is less resistant to snow moulds. Several observations and experiments have documented a clear genetic effect: northern timothy varieties are more resistant to snow mould than more southern adapted (Sjøseth 1957, Andersen 1966, Årsvold 1977). Nordic evaluation of test methods showed also good resistance for the northern cultivar 'Vega' (Pulli *et al.* 1996).

Breeding methods

Traditional methods

Phenotypic selection based on single plants or cloned plants has been and is still widely used in timothy breeding. Most breeders use a type of recurrent selection based on different crossing systems and progeny testing (Schjelderup *et al.* 1992). The crossing systems used have been Polycross and Topcross, producing half-sib families, and Pair cross, giving full sib families.

Plants from the best families with respect to special characters or overall value continue to the next round of crossing and progeny testing. To increase wanted variation new material such as commercial varieties or populations should be added in the cycle. Local populations have shown great variation, including variation which has in several characters exceeded commercial varieties (Torgersen Solberg *et al.* 1990, Larsen & Honne 2001). Even if local populations seldom possess all positive characters needed for a new cultivar, they are still important sources for future breeding. As environmental and technical conditions changes, it will be useful to go back to local populations for new genetic variation.

Syntheses of new candidate cultivars (candivars) may be done with selected parental plants, and randomly chosen plants or selected plants from the families.

Novel methods

Guo & Pulli (2000) first described production of green plants from androgenic embryogenesis in timothy. The microspore culture was genotype-dependent and albinism was a problem. About 60 per *cent* of the green plants were double haploids (6n=42).

Cai *et al.* (2003) developed 355 SSR (simple sequence repeat) markers for timothy. The markers detected 90.4% polymorphism between the parents of a pseudotestcross F population. The SSR markers will provide an ideal marker system to assist with gene targeting, QTL mapping, and marker-assisted selection in timothy.

Guo *et al.* (2003) demonstrated that methods based on molecular fingerprinting (combined RADP and UP-PCA) could be used for timothy identification, and identify the genetic background of genotypes used in timothy breeding. Thirty genotypes from fifteen countries were distinguished according to geographic groups.

In plant breeding the utilization of heterosis is important in developing new cultivars. In forage breeding a lot of emphasis has been put on population improvement and on developing synthetic cultivars from adopted material. Heterosis is based on the selection of genetically distant clones that will form the basis of new synthetic cultivars. New molecular techniques for characterization of timothy populations and clones can be used to identify genetically distant genotypes. These techniques can be used to exploit the exotic germplasm from other genebank collections. Maybe this source of variation could be used more in the timothy breeding programs even though the accessions are not adapted to our climatic conditions. A prerequisite for this is the ability to estimate genetic differences between populations and identify superior populations and genotypes to be used in new crosses.

Kölliker *et al.* (2005) studied the effect of increased AFLP diversity among parental plants on polycross progenies in perennial ryegrass. Syn1 and syn2 progenies derived from wide polycrosses showed consistently higher dry matter yields when compared to progenies derived from narrow polycrosses. Averaged across both generations and all maturity groups, this difference reached 3.7% and was highly significant. Their study provides evidence for an effective application of molecular markers to select genetically diverse parents in a polycross breeding program in order to increase agronomic performance of synthetic progenies without compromising phenotypic uniformity.

Breeding program

Breeding programs can be based on breeding populations for specific climatic areas and type of agronomic use as proposed by Solberg *et al.* (1990) and Aastveit & Aastveit (2004). As an example the Nordic countries could be divided into four regions, each with one breeding population for forage timothy, and in addition perhaps two regions with breeding populations for intensive cutting and grassing. To maintain genetic variation and to continue an increase over selection cycles, exchange of selected plants between breeding populations should be practiced, with some introduction of selected exotic materials.

Novel laboratory techniques for creation of new variation, marker assisted selection for desired characters and description of genotypes should be combined with traditional crossing, testing and selection work. The work including crossing, progeny testing, selection and syntheses of new cultivars has to be done in the actual regions. Early breeding materials have to be tested in environments which give genetic variation for the important characters (Solberg *et al.* 1990). Novel plant genetic techniques and forage quality analyses could be specialized at central laboratories.

Winter hardiness should be evaluated both under suitable field conditions and in controlled environments. Controlled freezing tests, especially for timothy, have shown a high correlation with mean field survival over several locations (Pulli *et al.* 1996).

Field and other observations have to be taken in close connection with the actual breeding goals. A selection index should be worked out to select the best genetic materials for new varieties and for continued breeding.

Conclusions

Important goals for future breeding:

- Improved fodder quality with no reduction in total DM yield.
- Adaptation to changing climate and management conditions.
- Establishment vigour and competition with weeds.
- N-use efficiency.

Future breeding strategies:

- Better basic genetic knowledge about the important grass timothy should be worked out.
- Novel laboratory techniques and conventional breeding methods should be combined.
- Breeding populations should be established for international geographic regions and for management systems.
- Development of selection indexes for better selection of adequate genetic materials.

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Oral presentations: Varieties

Sláttuvísa (1)

Fellur vel á velli
verkið karli sterkum,
syngur enn á engi
eggjuð spík og rýkur
grasið grænt á mosa,
grundin þýtur undir,
blómin bíða dóminn,
bítur ljár í skára.

Mowing Song (1)

Swishing, stripping, slashing,
slowly he goes mowing,
scythe-blade lashing lithely,
lethally beneath him.
Gallant flowers are falling,
fate betrays the daisies.
Iron edge is tireless;
under him, earth thunders.

SNORRI – A new Nordic timothy variety for areas around the Arctic circle.

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Background

In 1981 a joint Nordic breeding programme, Nordgrass, was initiated with the primary aim of developing fodder grass varieties that possessed broad adaptation to a range of Nordic climates and managements. The following national institutions, that existed at the time, co-operated in the breeding project: The Agricultural Research Centre, the Research Station for Lappland, Apukka, Finland (66°35'N); Svalöf AB, The Northern Branch, Röbäcksdalen, Sweden (63°49'N); The Norwegian State Agricultural Research Stations, Vågønes (67°17'N) and Holt (69°39'N), Norway; The Agricultural Research Institute, Korpa, Iceland (64°09'N) and The Royal Veterinary & Agricultural University, The Experimental Station Højbakkegård, Denmark (55°44'N). A detailed description of the project has been given elsewhere (Helgadóttir and Björnsson 1994).

In the initial phase of the programme extensive variety trials were established across experimental sites in Iceland and the northern parts of Scandinavia. For timothy, no interactions were found between varieties and sites (Helgadóttir 1989) and, therefore, it was decided to set up a common breeding project for this species with the aim of producing a variety that could be used across the whole region.

A polycross consisting of 12 timothy genotypes from each of the five northern research stations, making a total of 60 genotypes, was planted at Højbakkegård, Danmark in the spring of 1985. The polycross followed the layout proposed by Olesen & Olesen (1973). Progeny testing trials were then established at all five test stations in the spring 1987. It consisted of 60 half-sib families and four reference varieties, Bottnia II and Saga from Sweden, Bodin from Norway and Adda from Iceland, making a total of 64 entries. Based on the results obtained from these trials two synthetic populations, NOR1 and NOR2, were subsequently created and made available for extensive variety trials (Helgadóttir, Björnsson & Kristjánsdóttir, 1995). NOR1 is made up of a total of 16 genotypes of which three originated from Apukka, two from Korpa, one from Holt, seven from Vågønes and three from Röbäcksdalen. NOR2 is a narrower selection and is made up of a total of nine genotypes of which two each are from Apukka, Korpa, and Röbäcksdalen and three from Vågønes. NOR2 has obtained an UPOV technical examination and variety description and been given the name SNORRI.

In order to compare the outcome of the Nordgrass timothy breeding effort with timothy varieties already on the market, extensive variety trials were undertaken under the auspices of the programme. Here we will present summarized results from these trials.

Materials and methods

Three series of standard variety trials were established at a number of sites across the northern regions in 1994 (Apukka, Sotkamo, Ruukki (F), Holt, Vågønes, Løken (N), Röbäcksdalen, Lännäs (SE), Korpa, Hvanneyri (IS)), 1996 (Apukka, Sotkamo, Ruukki (F), Holt, Vågønes, Løken (N), Röbäcksdalen, Lännäs (SE), Korpa, Hvanneyri, Þorvaldseyri (IS)), and 1998 (Apukka, Ruukki (F), Holt, Vågønes, Løken (N), Lännäs (SE), Korpa, Hvanneyri, Stóra-Ármót (IS)) (Figure 1). The trials included, in addition to the two synthetic populations from the Nordgrass timothy breeding project, seven timothy varieties. However, not all varieties were present at all sites and years (Table 1). The trials were generally harvested twice a year for three years, following the establishment year. In some cases, results are not available for all three years because of poor winter survival. There were two different cutting treatments for the first cut: at the time of heading or two weeks after heading. The aftermath was taken six weeks after heading for both treatments.

Results from each series have been analysed separately for each site and across sites using standard ANOVA. Yield was generally dominated by environmental effects (locations and years) and yield differences between varieties were relatively small. In order to reduce the environmental effects and combine results from all sites, agroclimatic zones for performance testing of timothy in the Nordic countries as defined by Björnsson (1993) were adopted for the present analyses. The experimental sites fall into three zones: the Icelandic sites, together with Apukka and Holt, fall into the northernmost zone (Zone 1); Sotkamo. Ruukki, Vågønes and Løken into the second (Zone 2); and Röbäcksdalen and Lännäs in the third zone (Zone 3).

As both number of varieties included in each experiment and number of sites varied between zones, variance components were estimated for each zone separately using the Residual Maximum Likelihood Analysis for non-orthogonal data in Genstat Version 7.1 (Laws Agricultural Trust, 2003). Variety is the fixed factor and location × years (experimental years) is the random term in the model. Differences between varieties were tested using the average standard error of differences ($P<0.05$).

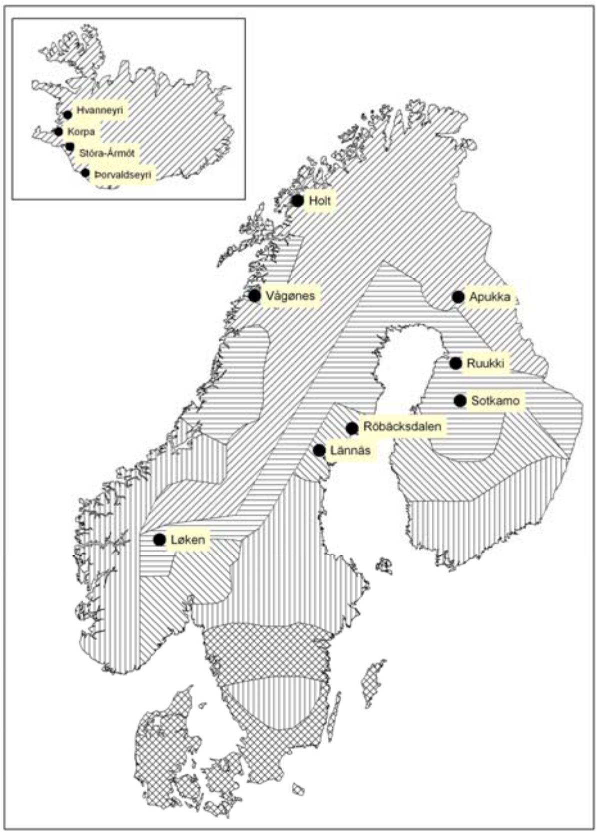

Figure 1. Experimental sites for variety trials testing the outcome of the Nordgrass timothy breeding project and schematic presentation of zones for timothy based on Björnsson (1993).

Results and discussion

Sites in Zone 1 had lower mean yields compared to sites in Zones 2 and 3 or 6.94, 8.31 and 8.28 t $ha^{-1}yr^{-1}$ respectively (Table 1). All varieties yielded similarly in Zone 1 apart from

Grindstad, which yielded significantly less than Snorri, NOR 1, Vega and Bodin. In Zones 2 and 3, on the other hand, Grindstad, yielded significantly more than all other varieties. Snorri yielded significantly more than Jonatan, Bodin and Adda in Zone 2.

The results obtained demonstrate that the new timothy variety Snorri seems to be well adapted for the range of climates that prevails in these regions. In the northernmost part it equals recent additions to the variety list such as Vega and in more favourable regions it certainly performs better than the most northern types such as Adda and Bodin. Snorri shows overall good stability across the whole region even though it did not show clear advantages over Vega, Tuukka and Iki in these trials.

Table 1. Number of experimental years (yr) and mean total yield (t $ha^{-1}yr^{-1}$) in the three agroclimatic zones for each variety included in the Nordgrass variety trials.

	Zone 1[1]		Zone 2[2]		Zone 3[3]	
Variety	yr	yield	yr	yield	yr	yield
SNORRI	13	7.05	8	8.49	3	8.18
NOR 1	40	7.04	30	8.28	12	8.22
Tuukka	39	6.88	30	8.37	12	8.49
Iki	27	6.96	22	8.40	9	8.23
Vega	28	7.04	18	8.36	7	8.18
Jonatan	40	6.86	30	8.11	12	8.13
Bodin	27	7.06	22	8.03	9	8.01
Adda	40	6.86	30	7.80	12	7.84
Grindstad	27	6.74	22	8.97	9	9.24
Mean		6.94		8.31		8.28
s.e.d.		0.12		0.16		0.28

[1] Zone 1: Apukka, Holt, Korpa, Hvanneyri, Thorvaldseyri, Stóra-Ármót
[2] Zone 2: Sotkamo, Ruukki, Vågønes, Løken
[3] Zone 3: Röbäcksdalen, Lännäs

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Yield stability of timothy varieties in the Swedish VCU-testing

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Abstract

The phenotypic stability of yield for four Swedish-bred timothy varieties was compared for six varieties of timothy from abroad. Data from the official variety testing in Sweden from the period 1996 to 2005 were analysed. A regression method was used to determine phenotypic stability (B), analysing the slope when the actual site-yield for a variety was plotted against the average yield for the site. Values of B equal to 1.00, greater than 1.00 and less than 1.00 represent average, greater than average and less than average sensitivity, respectively. The results showed few significant differences in phenotypic stability between the timothy varieties, even though they have a broad geographic origin. The Swedish variety Carola was the most unstable (B = 1.14) and the Norwegian variety Noreng was the most stable (B = 0.76) in the first harvest the second year of ley. The varieties were similar in yield in this harvest.

Introduction

The origin of timothy (*Phleum pratense* L.) varieties tested in Sweden has expanded during the last ten years. Many of the varieties from abroad have competed very well with the Swedish-bred varieties when comparing the yield (Halling 2005). But do foreign varieties differ in yield stability compared to varieties bred in Sweden? As one of the main breeding objective is yield stability, it is important to be able to identify those varieties which have a high and stable yield. Various methods are available to analyse this stability or genotype x environment interaction. It is rather simple to determine the stability as a slope in a linear regression between the actual site-yield for a variety and the average yield for the site. The purpose of the present paper is to determine if there are any differences in yield stability between Swedish-bred and foreign-bred timothy varieties under Swedish conditions.

Materials and methods

The data originated from the Swedish variety testing of timothy during the period from 1996 to 2005. Trials have been conducted between latitude N 60°17' and N 55°32' at ten major sites. The testing periods have been an establishment year and two harvesting years, with two harvests each year. The first harvest was taken at heading (when half the head was visible on more than half of the shoots). Among the ten varieties presented in this paper, four are from Sweden (Alexander [65], Carola [18], Jarl [24] and SW TT2528 [12]), one from Norway (Noreng [10]), one from Finland (Tuukka [6]), one from Denmark (Tundra [9]), one from Germany (Liglory [31]) and one from Canada (Glacier [11]). Numbers in brackets are the individual trials for each variety. Alexander was used as the check in the trials.

The model described by Eberhart & Russell (1966) was used to determine the phenotypic stability:

$$Y_{ij} = m + B_i E_j + \delta_{ij} + \varepsilon_{ij}$$

where Y_{ij} = performance of the i-th variety in the j-th environment, m = general mean, B_i = regression coefficient of the i-th variety, E_j = environmental contribution of the j-th environment obtained by the mean of each environment, δ_{ij} = the regression deviation of the i-th variety in the j-th environment and ε_{ij} = effect of the mean experimental error. Values of B_i are used as a relative measure of the sensitivity of the varieties to changes in environmental stress. Values of B equal to 1.00, greater than 1.00 and less than 1.00 represent average, greater than average and less than average sensitivity, respectively.

Results

The phenotypic stability is presented in Table 1. There were overall significant differences between values in all harvests, except second harvest in ley year 1. Making contrasts with Alexander as a check, Carola had a significantly higher B-value in the first harvest in ley year 1 ($p<0.0354$) and in ley year 2 ($p<0.0053$). In the first harvest, Noreng had a significantly higher B-value in ley year 1 ($p<0.0015$), but a significantly lower B-value in ley year 2 ($p<0.0138$), compared with Alexander. Finally, Tundra had a significantly higher B-value in the first harvest in ley year 1 ($p<0.0367$) and Noreng had a significantly lower B-value in the second harvest in ley year 2 ($p<0.0000$), compared with Alexander.

Table 1. Phenotypic stability (regression coefficient = B) for the harvests in first and second year of ley.

	First harvest		Second harvest	
Variety	ley 1	ley 2	ley 1	ley 2
Alexander	0.97	0.95	1.01	1.00
Carola	1.15	1.14	1.00	1.03
Comtal	0.91	0.99	0.89	0.99
Glacier	1.05	1.03	0.88	0.98
Jarl	0.93	0.99	0.92	0.99
Liglory	0.98	1.02	0.94	1.03
Noreng	1.24	0.76	0.95	0.74
SW TT2528	0.91	1.05	1.08	1.00
Tundra	1.15	0.94	1.00	1.08
Tuukka	1.17	0.99	0.54	0.88
Probability (*p*)	*0.007*	*0.011*	*0.403*	*0.000*

In Table 2, the differences in dry matter (DM) yield are shown (Source of data: Fältforsk http://www.ffe.slu.se/Sve/index.cfm?SBody=R). Compared to Alexander, there were no significant differences in yield of Carola and Noreng in the first harvest in both ley years, but in the second harvest Noreng had a significantly lower yield in ley year 2 ($p<0.001$).

In Figures 1 and 2, the regression lines are shown for the most stable and unstable varieties in the first harvest in the second ley year.

Discussion

Overall there were few significant differences in phenotypic stability between the timothy varieties, even though they have a broad geographic origin. This result probably reflects that fact that both foreign varieties introduced in Sweden were pre-selected for good performance before applied in the testing and that the natural origin of timothy is close to the Swedish growing conditions.

Table 2. Dry matter yield (DM) in first and second harvests in the two years of ley over the period 1996-2005.

	First harvest		Second harvest	
Variety	ley 1	ley 2	ley 1	ley 2
Alexander	100	100	100	100
yield kg DM ha^{-1}=100	5964	6146	4892	3855
Carola	98	101	96	98
Comtal	95	100	89***	94
Glacier	88***	103	92***	89***
Jarl	101	102	95***	99
Liglory	102	105***	98	100
Noreng	101	101	72***	66***
SW TT2528	99	106**	108***	110***
Tundra	105*	101	88***	86***
Tuukka	n/a	n/a	n/a	n/a

*p>0.05; *p<0.05; **p<0.01; ***p<0.001*

n/a = data not available

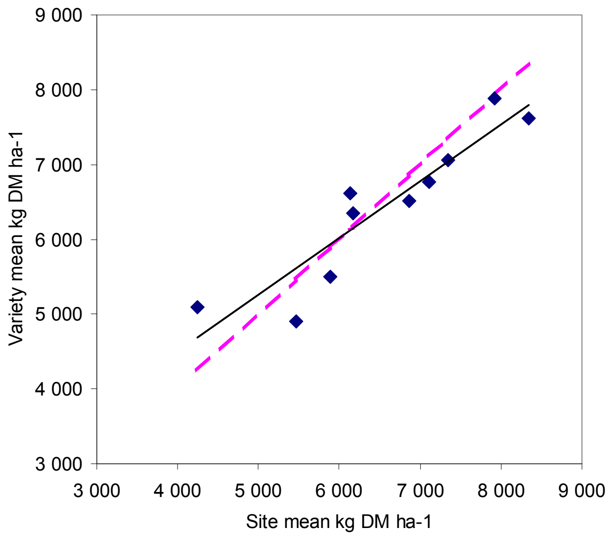

Figure 1. The most stable variety Noreng in the first harvest, the second year of ley. The slope of Noreng, B=0.76, is shown by the line (—). In the figure are also observed yields (◊) and the B=1.00 line (----) presented.

The Swedish variety Carola and the Norwegian variety Noreng were two extremes in the stability in the first harvest in the second ley year ley, Carola being the most unstable (B = 1.14) and Noreng being the most stable (B = 0.76). Interestingly, they had the same yield in this harvest. Obviously, the phenotypic stability gives different information compared to the yield. Should phenotypic stability be introduced in the evaluation of the variety testing, which at the moment is mainly based on the yield observations? In breeding, the use of phenotypic stability has been valuable (Helgadóttir & Kristjánsdóttir 1991).

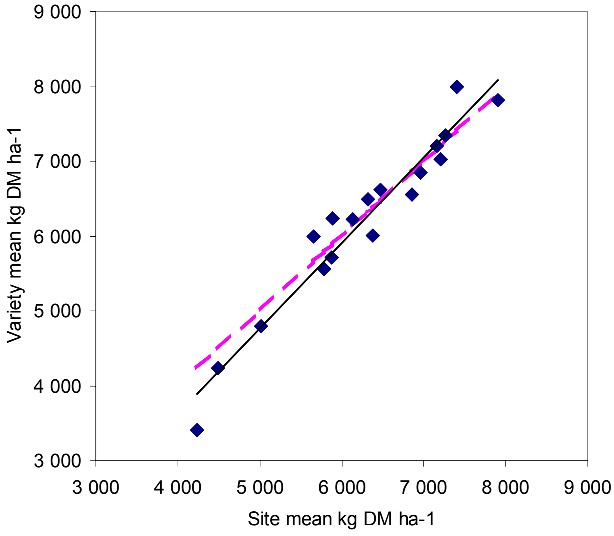

Figure 2. The most unstable variety Carola in the first harvest, the second year of ley. The slope of Carola, B=1.14, is shown by the line (—). In the figure are also observed yields (◊) and the B=1.00 line (----) presented.

However, the conclusion of stability should be drawn carefully, since Carola and Noreng did not always occur in the same trials. From the results, Noreng should be the best choice in the first harvest in the second ley year because of its high stability in this situation. However, the total yield of Noreng was poor in the second ley year because of a low regrowth (Table 2). On the other hand, the sensibility of Noreng was high in the first harvest in the second ley year .

Is there any advantage to a more sensible variety? A more sensible variety had a higher yield potential, but the results gave no clear pattern as to which sites or which years had the highest yields.

Conclusions

Few significant differences in phenotypic stability between the timothy varieties were detected. When comparing varieties, phenotypic stability and DM yield can give different information.

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Growth and development of frost tolerance in eight contrasting cultivars of timothy and perennial ryegrass during winter in Norway

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Introduction

The global temperature is expected to increase by 1.4-5.8°C during the next 100 years, an increase that is related to a parallel atmospheric CO_2 increase of up to 478-1099 ppm (IPCC 2001). The temperature rise in the northern parts of Norway will probably be larger than in the southern parts. Generally, a much more variable climate with frequent fluctuations between frost and mild weather, more precipitation as rain, more ice encasement, water logging, and less snow cover are expected during winter in Norway (IPCC 2001, RegClim 2005).

How will the expected climate change affect overwintering of important agricultural crops? The question is addressed in the Norwegian research program WINSUR (2004-2008). The overall aim of WINSUR is to predict the effect of climate change on winter survival of forage grasses and winter wheat, including the development of weeds in wheat and snow mould fungi in both crops. The aim of the present study, which forms a part of WINSUR, is to provide a detailed picture of the growth and development of contrasting cultivars of timothy and perennial ryegrass during winter. The data will be used in the development of a simulation model for grass overwintering, for use in the climate change study.

This study was funded by the Norwegian Research Council and Bioforsk as part of the WINSUR (Climate change effects on winter survival of perennial forage crops and winter wheat and on plant diseases and weed growth and control at high latitudes).

Material and methods

Four contrasting varieties of timothy (*Phleum pratense* L.); Engmo (N. Norway), Grindstad (S. Norway), Jauniai (Lithuania), S48 (Great Britain) and four varieties of perennial ryegrass (*Lolium perenne* L.); Riikka (Finland), Gunne (Sweden), Veja (Lithuania), S23 (Great Britain) were established at Holt (69º N, 40 m above sea level [a.s.]), and Særheim (58º N, 90 m a.s.). Both locations are on the coast. Small swards were established in May (Særheim) and June (Holt) in 10 l black polyethylene bags filled with a fertilized sand-peat mixture, 10 seedlings *per* bag, and placed in the field, ca. 20 bags *per* m^2. The plants were cut twice during the growing season, leaving a 5 cm stubble. The first cut was performed in mid-July and the last on 30-31 August at Holt and 12 September at Særheim. Destructive sampling was performed from October (Holt) or November (Særheim) to April, on five occasions in total, for determination of biomass in leaves lamina (cut at ligula), leaf sheaths + pseudostems (tiller bases), and dead material above ground. The number of tillers per pot were counted. Freezing tests were performed to determine the temperature at which 50% of the population died (LT50). Tillers were trimmed to 3 cm top and 1 cm root, put in moist sand and frozen in a computer-controlled freezer. The temperature was decreased by 1°C h^{-1}, except at –3°C where it was held constant for 10-15 h, and then decreased again by the prior rate. Two bundles with 10 tillers per cultivar were removed from the freezer at five different temperatures appropriate for the anticipated hardiness. After thawing, the frozen tillers together with unfrozen control tillers were planted in pots filled with peat and placed in a heated greenhouse for three weeks, when mortality was recorded and LT50 estimates were derived from these data by probit analysis using Minitab.

Results

Weather

At Særheim, the autumn was slightly warmer than normal, whereas January to April was significantly colder, with especially cold weather in March (Table 1). At Holt, every month from autumn to spring was warmer than normal, except March. January was notably mild. All mean monthly temperatures were lower at Holt than Særheim. The first screen frost occurred in September at Holt and November at Særheim. From there on, screen frosts occurred in every month until the end of the experiments. At Særheim, the ground was bare throughout most of the winter. The exception was a period of ca. three weeks in March and a few shorter spells in the preceding months when the ground was covered by snow, generally not more than 10 cm deep. At Holt, there was snow from the end of November to the beginning of April, except for a period of ca. 3 weeks January. After a mild and wet period in January, ice accumulated to varying degrees in the pots at Holt.

Table 1. Mean monthly temperatures (°C), soil temperature, and precipitation (mm) during the experimental period, with 30-year averages in brackets, from on-location weather stations. The soil temperature was measured at 10 cm depth at an adjacent short-cut grass field.

	Særheim			Holt		
Month	air temp.	soil temp.	precip.	air temp	soil temp	precip.
August	13.5 (14.9)	15.1	133	11.6 (11.0)	11.7	135
September	12.6 (12.2)	13.5	191	7.4 (7.0)	8.4	143
October	10.6 (8.3)	10.3	129	5.6 (3.3)	6.1	210
November	5.8 (4.9)	7.4	200	2.2 (0.0)	3.2	95
December	3.2 (2.5)	3.7	79	-1.3 (-2.5)	0.5	41
January	1.5 (2.6)	1.3	98	0.9 (-3.5)	0.2	110
February	1.5 (2.0)	1.5	103	-1.7 (-4.0)	0.1	132
March	-0.4 (3.2)	1.5	20	-3.4 (-2.3)	-0.1	83
April	4.7 (6.3)	5.5	134	3.4 (0.7)	0.0	18

Tiller density

Values for tiller numbers averaged over cultivars are shown in Figure 1. In December there were 2-3 times more tillers in perennial ryegrass compared with timothy, but due to a much more rapid loss of ryegrass tillers throughout the winter much of the difference between the species levelled out. At Særheim, timothy and perennial ryegrass lost, respectively, 10 and 42% of their tillers during the winter, averaged over cultivars. At Holt, timothy and ryegrass lost, respectively, 42 and 85% of their tillers during the winter. Comparatively larger differences in tiller density and tiller loss during the winter were found among the ryegrass cultivars compared with the timothy cultivars (not shown). Gunne showed the largest decline in tiller numbers among the ryegrass cultivars at Særheim, whereas Riikka showed the largest decline at Holt. Engmo showed the most stable tiller population among the timothy cultivars at Holt. At Særheim, there was less apparent difference among the timothy cultivars.

Biomass

As for tiller numbers, perennial ryegrass had a higher leaf biomass than timothy in December, but ryegrass lost more of its leaf biomass during the winter than timothy, levelling out the differences among species to similar values in spring (Figure 1). All cultivars, irrespective of species, maintained some leaf mass throughout the winter, although in some cultivars the minimum was below 0.1 g pot^{-1}. The minimum for leaf biomass, for all cultivars, was reached in March at Særheim, whereas at Holt the plants continued to lose biomass until

April. At Særheim, the picture for biomass of tiller bases was similar to that of the leaves, except that the minimum level of tiller base biomass was reached in April (not shown). Individual tiller bases were generally higher at Særheim compared to Holt (not shown).

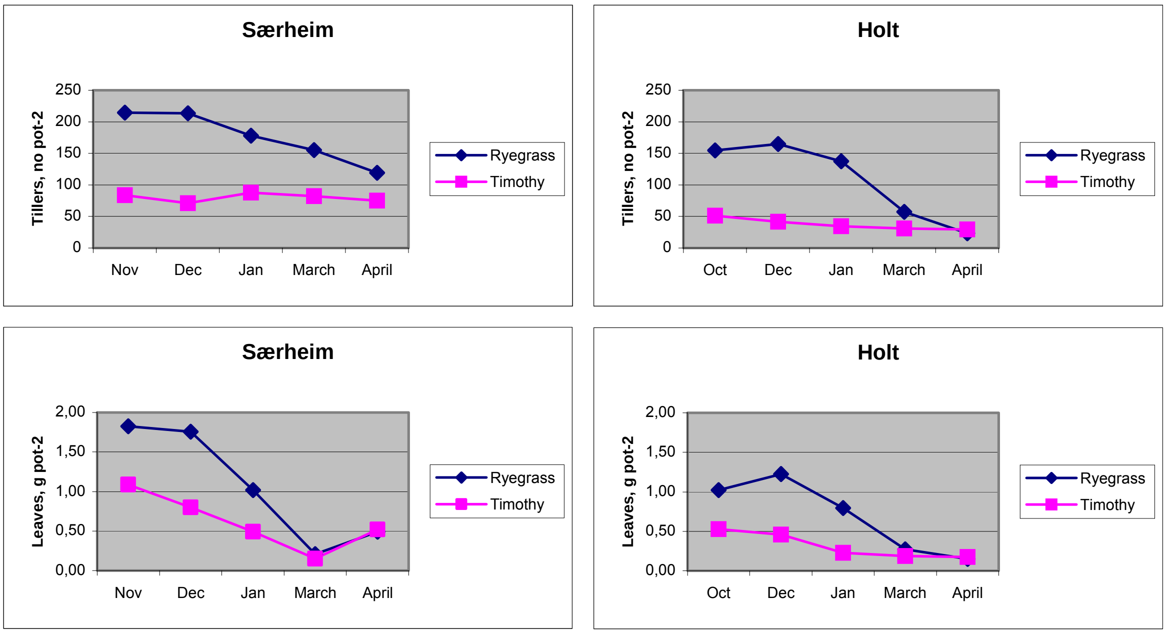

Figure 1. Number of tillers and dry weight of leaves per pot (ca. 20 pots m^{-2}) at Særheim and Holt in the winter of 2005-2006. Mean values for four cultivars per species.

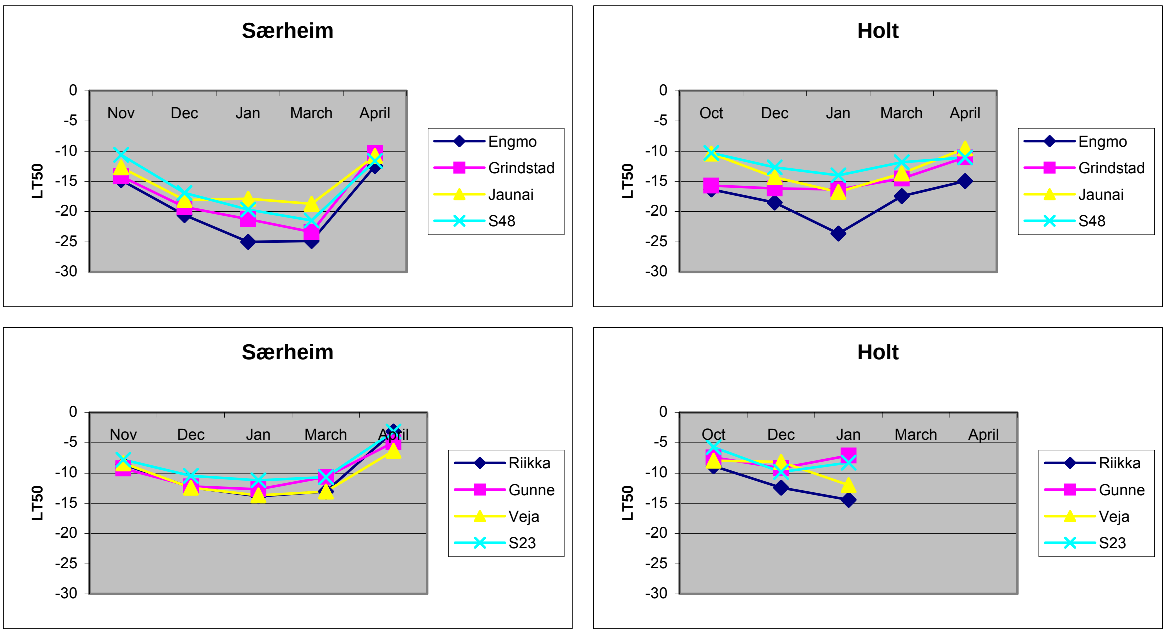

Figure 2. Frost tolerance (LT50) in different cultivars of timothy (the uppermost figures) and perennial ryegrass (the ones below) at Særheim and Holt in the winter of 2005-2006.

LT50

All timothy cultivars except Engmo and all ryegrass cultivars except Riikka reached higher frost tolerance at Særheim than Holt (Figure 2). At Særheim, all ryegrass cultivars showed their highest frost tolerance in January, whereas the timothy cultivars showed their maximum in March. At Holt, all cultivars of both species showed their maximum frost tolerance in January. Substantial dehardening occurred from March at Særheim, and from January at Holt. At Holt, it was impossible to calculate LT50 values for the ryegrass cultivars in March and April since the tillers were so weakened by the winter that they did not even survive the unfrozen control treatment. The greatest difference in maximum frost tolerance between Særheim and Holt was observed for Grindstad and S48 timothy (ca. 7°C difference) and Gunne perennial ryegrass (ca. 3°C). For the other cultivars the difference was within 1-2°C.

Discussion

The more “opportunistic” perennial ryegrass produced more leaves during the autumn and it held a much higher tiller density in the autumn than the timothy. A high number of tillers often give perennial ryegrass an advantage during the growing season: it can regrow faster and withstand more frequent defoliation than timothy. The more “conservative” growth characteristics of timothy, on the other hand, provide advantages during the winter: it can achieve a higher level of winter hardiness to better withstand physical stress factors like frost and ice encasement and biological stress factors like fungal diseases. These species differences were clearly evident in the present study. Thus, timothy produced significantly fewer leaves in the autumn, but on the other hand it achieved a higher level of frost tolerance and lost significantly fewer of its tillers during the winter compared to the ryegrass.

Most cultivars achieved a higher level of frost hardiness at Særheim than at Holt. The exception was Engmo timothy that achieved a similar frost tolerance at both locations, and Riikka perennial ryegrass that reached its lower LT50 at Holt. It is interesting to note that Engmo is the most northern of the timothy cultivars. Riikka is the most winter hardy of the ryegrass cultivars. However, a more complex genetic background makes it difficult to distinguish northern and southern ecotypes among the ryegrasses. It can be speculated whether the different day lengths and/or the different temperature conditions explain the interaction between site and cultivar for frost hardiness.

The partial ice encasement in the pots at Holt can probably explain, to a large degree, the rapid loss of frost tolerance from January to March. At Særheim there was no ice in the pots and the frost tolerance increased from January to March, probably as a result of the many frost days. It is well known that ice encasement can severely reduce the frost tolerance in grasses and that timothy withstand ice encasement better than perennial ryegrass (Gudleifson & Larsen 1993). LT50 values <-30 °C has been observed at Ås, an inland site in Norway with long and stable winters (Larsen 1994). Thus, the potential was never reached in the present experiment. Long periods of sub-zero temperatures are required for the last stage of hardening when maximum frost hardiness is reached.

We are awaiting analysis of the carbohydrate and nitrogen content of the plants. The data will be used in the development of a simulation model for grass overwintering. A major challenge in the modelling seems to be the interaction between ice encasement and frost hardiness: on one hand, frost hardiness and ice encasement tolerance are often positively correlated; on the other hand, ice encasement can severely reduce frost hardiness.

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Timothy and other grasses in Lithuania: Stability and yield

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Abstract

Stability and dry matter yield (DMY) (three cuts per growing season) were investigated of 6 forage grass species in field trials in Lithuania over the period of 1989-2002 .

The most productive species of the first cut of two years of herbage utilization were *Phleum pratense* ($P < 0.01$) and *Festulolium* hybrids ($P < 0.05$) (average DMY were 7.42 and 6.66 t ha^{-1} respectively), moderately productive - *Festuca pratensis*, *Dactylis glomerata* and *Lolium perenne* (5.58, 5.42 and 5.20 t ha^{-1}); *Poa pratensis* (4.19 t ha^{-1}) was significantly lower yielding ($P < 0.01$).

The coefficient of variance of the 13 year DMY of the first cut of individual species shows that in the first and separately in the second year of use *Phleum pratense* was most stable in this respect. The coefficient of variance of *Phleum pratense* was -18.6 % for the first year and 28.2 % for the second year, whilst the least stable in the first year of herbage use was *Poa pratensis* (40.2 %), and in the second year *Lolium perenne* (49.5%).

During two years of herbage utilization *Dactylis glomerata* produced a significantly ($P < 0.01$) higher DMY of aftermath - 7.30 t ha^{-1}. Other grass species were ranked in the following order: *Festulolium* hybrids - 5.85 t ha^{-1}, *Festuca pratensis* - 4.94 t ha^{-1}, *Poa pratensis* - 4.57 t ha^{-1}, *Lolium perenne* - 4.48 t ha^{-1}, and *Phleum pratense* - 3.92 t ha^{-1}. *Dactylis glomerata* and *Poa pratensis* stood out with the highest aftermath percent in the structure of the annual DMY (57.7 % and 52.2 %). *Phleum pratense* formed an especially poor aftermath, only 34.6 %. The low DMY was determined by a poor regrowth after cuts.

Coefficient of DMY variance of aftermath of two years of use was large for all species investigated and ranged from 38.3% (*Dactylis glomerata*) till 45.7% (*Phleum pratense*).

Key words: aftermath, coefficient of variance, correlation, first cut, regrowth

Introduction

The major forage grasses currently cultivated in Lithuania are timothy (*Phleum pratense L.*), ryegrass–fescue hybrids (*Festulolium*), meadow fescue (*Festuca pratensis* Huds.), perennial ryegrass (*Lolium perenne* L.), cocksfoot (*Dactylis glomerata* L.) and Kentucky bluegrass (*Poa pratensis* L.). A very important property of forage grasses is their ability to give stable and high dry matter yield. The level of the productivity and stability mostly depends on the genetic potential of the forage grass species (Chapman *et al.* 1996, Martinello 1998, Lemežienė *et al.* 1999). Literature sources provide various data of the dry matter yield of major perennial grasses ((Kadžiulis 1972, Waldron *et al.* 2002). The shortcoming of these data is that the trials are not comparable, since they were not conducted in the same experimental year, did not covered several years and did not describe grass species, as only a few, or most often even one variety, were investigated.

The objective of this study was to analyse the dry matter yield (DMY) of the first cut and aftermath of 6 forage grasses in relation to agronomically valuable characteristics of the species and year of herbage use and to ascertain the most productive and stable species in this respect.

Materials and methods

The perennial grasses were tested in the Central Lowland of Lithuania, where the annual amount of precipitation is 520-700 mm and mean air temperature 6.3° C (Bukantis *et al.* 2001).

Competitive variety trials of perennial ryegrass, meadow fescue, timothy, cocksfoot, and ryegrass-fescue hybrids were assessed over the period 1989-2002 (13 annual variety testing trials of each grass species).

The duration of one trial was two years of herbage use (excluding the sowing year). Altogether 779 varieties and breeding lines including 127 perennial ryegrass, 134 meadow fescue, 214 timothy, 104 cocksfoot, 100 ryegrass-fescue hybrids, 100 Kentucky bluegrass were tested during these years.

Grasses were sown with four replications. Plot area ranged from 9.5–10.5 m². In the autumn of each year of use phosphorus and potassium fertilisers (P_{60} K_{90}) were applied. Nitrogenous fertilisers (N_{150}) were applied each year of herbage use in several applications: in spring N_{60}, and N_{45} after the first and second cut. The grasses were sown in the first half of June without a cover crop. The first cut was taken at the beginning of heading of different species, the second and third cuts were taken after the regrowth of aftermath.

Each year's experimental data were processed by one-or two-factorial dispersion analyses. In order to reveal differences among the grass species and between the years of utilization, the averaged data were processed by two-factorial analyses according to the scheme: species × year of herbage use (Clewer & Scarisbrick 2001).

Results

DMY and coefficient of variance of first cut

According to 13 year averages of DMY of the first cut it was determined that the most productive species were timothy (P_{099}) and ryegrass-fescue hybrids (P_{095}). Their average DMY of the first cut during two years of use were 7.42 and 6.66 t ha^{-1}, respectively, significantly (P_{099}) lower yielding was Kentucky bluegrass (4.19 t ha^{-1}), and the following were moderately productive species: meadow fescue, cocksfoot and perennial ryegrass (5.58, 5.42 and 5.20 t ha^{-1})(Figure 1).

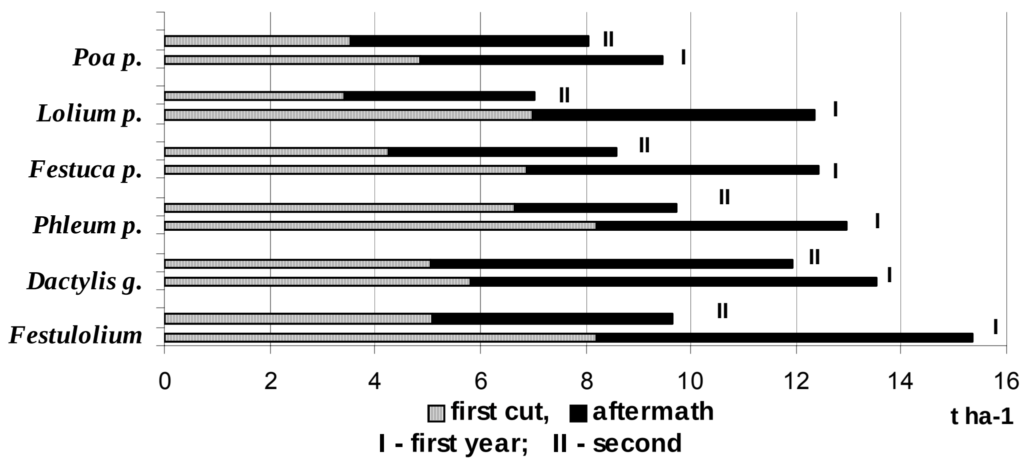

Figure 1. Average annual dry matter yield.

The coefficient of variance of the 13 year DMY of the first cut of individual species showed that in the first and separately in the second year of use timothy was most stable in this respect.

The coefficient of variance of timothy for the first year was 18.6 % and 28.2 % for the second year. Small variations (coefficient of variance 18.6 %, Table 1) of the DMY of the first cut of timothy were determined by their very good overwintering, adequate field germinating ability in the sowing year and a distinct relationship between the yield and effective accumulated temperatures from the start of the period of vegetative growth to the first cut (Lemežienė *et al.* 2000).

The least stable in the first year of herbage use was Kentucky bluegrass (40.2 %), and in the second year, perennial ryegrass (49.5 %). In the first year of herbage use the unstable DMY of the first cut of Kentucky bluegrass was mostly determined by poor field germinating ability and establishment in the sowing year (Table 1).

Table 1. Agronomically valuable characteristics and an average dry matter yield of 1st cut and its variation.

Characteristic	*Phleum pratense*	*Festu-lolium*	*Dactylis glomerata*	*Festuca pratensis*	*Lolium perenne*	*Poa pratensis*
		1st year of herbage utilization				
Field germination (points)	6.5^{--}	8.5^{++}	7.5	8.0^{++}	8.5^{++}	4.7^{--}
Winter damage (points)	1.0^{++}	1.9^{-}	1.7	1.0^{++}	2.7^{--}	1.0^{++}
Earliness	very late	late	Early	interme-diate	late–very late	very early
Height at heading (mm)	784^{++}	792^{++}	760^{+}	704	513^{--}	449^{--}
Dry matter yield (t ha^{-1})	8.20^{++}	8.22^{++}	5.80^{-}	6.89	6.99	4.85^{--}
Coeff. of variation (%)	18.6	25.5	33.1	25.1	27.2	40.2
		2nd year of herbage utilization				
Winter damage (points)	1.0^{++}	2.8^{--}	2.4	1.2^{++}	4.4^{--}	1.0^{++}
Height at heading (mm)	693^{++}	659^{++}	700^{++}	546	400^{--}	368^{--}
Dry matter yield (t ha^{-1})	6.65^{++}	5.09	5.05	4.26	3.42^{--}	3.53^{-}
Coeff. of variation (%)	28.2	38.2	32.3	40.7	49.5^{--}	41.1

$^{+}$, $^{++}$ indicate the highest and $^{-}$, $^{--}$ - the lowest significant differences between means within the same rows at $P< 0.05$ and 0.01 probability levels, respectively.

This result is confirmed by the data found in the literature about the uneven field germinating ability and tillering of small-seeded and large-seeded grasses in the sowing year (Kryževičiene & Žemaitis 1997). Unfavourable overwintering conditions in the second year resulted in the greatest reduction in the dry matter yield of perennial ryegrass.

DMY and coefficient of variance of aftermath

The average data for the second and third cuttings of the first year of use show that a higher DMY of aftermath of all grass species was obtained in the second cut as compared to the third cut: 3.47 t ha^{-1} and 2.38 t ha^{-1} respectively (Table 2, Figure 1).

A reduction in the DMY at the end of the vegetative growth period when the third cut is forming can be explained by the fact that with senescence plants lose vigour, the rate of regrowth declines and additionally, plants often suffer from drought at the end of summer. The same trend is seen also in the second year of herbage use – the average DMY of the third cut was lower than that of the second cut, 2.66 t ha^{-1} and 1.84 t ha^{-1} respectively (Table 2, Figure 1). The average dry matter yield of the aftermath of all the investigated grass species in the first and second year of herbage use was 5.86 and 4.50 t ha^{-1}, respectively.

A good dry matter yield of cocksfoot aftermath in the first and second years of herbage use can be explained by an excellent regrowth of this grass species after cuttings and good drought resistance (Tarakanovas 1992, Kochanovska-Bukowska 2001). The yield of cocksfoot aftermath accounted for as much as 57.7 % of the annual dry matter yield (12.73 t ha^{-1}) (Figure 1). This is a trait by which cocksfoot distinguishes itself among the other grasses.

Kentucky bluegrass also had good regrowth capacity. The dry matter yield of the aftermath of this species (of the second and third cuts) during the two years of herbage use accounted for 52.2 % of the annual yield (8.76 t ha^{-1}).

Ryegrass–fescue hybrids, as compared with parental forms (meadow fescue and perennial ryegrass) gave a similar dry matter yield of aftermath (46.8, 47.0 and 46.3 % respectively).

The dry matter yield of aftermath in timothy accounted for only 34.6 % of the annual yield. The low dry matter yield of the aftermath was determined by a poor regrowth of the species after cuts.

The dry matter yield variation of the aftermath in the first year of use was: meadow fescue (27.4 %), cocksfoot (31.9 %), perennial ryegrass (33.2 %), ryegrass - fescue hybrids (35.0 %), Kentucky bluegrass (37.2 %) and timothy (41.9 %). The DMY variation of the aftermath in the second year of herbage utilization was higher than in the first year (Table 2). The coefficient of DMY variance of aftermath of two years of grass use was large for all species and ranged from 38.3% (cocksfoot) to 45.7% (timothy).

Table 2. Plant height before cuts and average dry matter yield of aftermath and its variation.

Characteristic	*Phleum pratense*	*Festu-lolium*	*Dactylis glomerata*	*Festuca pratensis*	*Lolium perenne*	*Poa pratensis*
1st year of herbage utilization						
Plant height before 2nd cut (mm)	420^{--}	754^{++}	689^{++}	359^{--}	499	449^{-}
Dry matter yield of 2nd cut (t ha^{-1})	2.98^{--}	4.37^{+}	4.36^{+}	3.10	2.98^{--}	3.04^{-}
Plant height before3rd cut (mm)	290^{-}	415	581^{++}	310	306^{-}	328
Dry matter yield of 3rd cut (t ha^{-1})	1.79^{-}	2.77	3.37^{++}	2.44	2.38	1.56^{--}
Coef. of variation of dry matter yield of aftermath (%)	41.9	35.0	31.9	27.4	33.2	37.2
2nd year of herbage utilization						
Plant height before 2nd cut (mm)	353^{--}	659^{++}	604^{++}	302^{--}	397	288^{--}
Dry matter yield of 2nd cut (t ha^{-1})	1.83^{--}	2.71	3.98^{++}	2.36	1.99^{--}	3.07
Plant height before 3rd cut (mm)	306	354	555^{++}	271^{-}	299	248^{--}
Dry matter yield of 3rd cut (t ha^{-1})	1.24^{-}	1.85	2.90^{++}	1.97	1.61	1.47
Coef. of variation of dry matter yield of aftermath (%)	49.4	42.6	44.6	52.1	40.8	46.4

$^{+}$, $^{++}$ indicate the highest and $^{-}$, $^{--}$ - the lowest differences from the average data significance at $P< 0.05$ and 0.01 probability levels, respectively.

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Oral presentations: Physiology and management

Sláttuvísa (2)

Gimbill gúla þembir,
gleður sig og kveður:
"Veit ég, þegar vetur
vakir, inn af klaka
hnýfill heim úr drífu
harður kemst á garða,
góðir verða gróðar
gefnir sauðarefni."

Mowing Song (2)

"Let's be glad!" the little
lamb bleats out and gambols,
"glad that when the winter
wakens, and they take me
from its dread and deadly
dangers to the manger,
loads of luscious fodder
lie there sweet and drying!"

Phenological development of timothy swards as assessed according to the numeric scale Mean Stage by Count

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Introduction

Phenological development is often included as a state variable in models and decision support tools simulating and predicting yield quality and quantity in spring growth of grasses (e.g. Gustavsson *et al*. 1995, Gustavsson *et al*. 2003, Höglind *et al*. 2001). In this context, there is a need for a growth staging system that uses consistent numeric codes on a continuous scale appropriate for the establishment of functional relationships between developmental rate and soil and weather factors.

Bonesmo (2004) has previously established a relationship between the daily rate of development in timothy, and day length and daily mean temperatures, that later is applied in a decision support tool for predictions of yield and quality (Gustavsson *et al*. 2003, Bonesmo & Bakken 2005). In the most recent version (Bakken *et al*. 2006a), Mean Stage by Count (MSC) (Moore *et al*. 1991) is implemented as the phenological scale. The rate coefficients for the daily changes and base temperatures and day lengths have so far been assumed and optimized to be constant for the whole period from the leaf stage until full heading.

With the overall aim of improving the phenological function of the decision support tool, we have here evaluated how appropriately the scale describes the continuum of phenological events in timothy and further suggested and tested adaptations to the previous equations describing the functional relationships between temperature and development.

Methods

From early spring until flowering in 2004 and 2005, timothy shoots from the uncut swards at three sites (Særheim, Løken, Kvithamar) described by Bakken *et al*. (2006b) have been sampled and classified according to the scheme developed by Moore *et al*. (1991). The number of samplings varied between sites and years (Table 1). At each sampling occasion, at least 40 tillers from the shoot population (every single one along a continuous line) were assessed, and a mean stage (MSC, 1-4) then calculated as described by Bakken *et al*. (2005).

The collected data were for all sites and years together fitted to Equation I in search of sets of α, T_b, Dl_b and Dl_m that minimised root mean square error of estimation (RMSE). The program package Powersim Solver was used (Powersim 1996).

$$\text{Eq I: } dP = \alpha\,(T - T_b)\,(\min(Dl, Dl_m) - Dl_b)$$

where dP is the daily rate of phenological development (d^{-1}), α is the rate coefficient, T is the daily mean temperature (°C), T_b is the base temperature (°C), Dl is the daylength (h), Dl_m is the maximum effective day length (h) and Dl_b is the base day length (h).

The start of the phenological development was assumed to be at the first passage of a 7-day period with daily mean temperatures higher than T_b.

To investigate the rate of development further, dP was weighted with a function, $f(P)$, attaining daily values from 0 to 1, dependent on MSC (Figure 1). This was done because dP seemed to vary according to stage of development. Parameters included and later optimised were P_m (MSC at which dP attains its maximum), P_0 (MSC at which development starts) and P_k (slope of the function in the "exponential" phase).

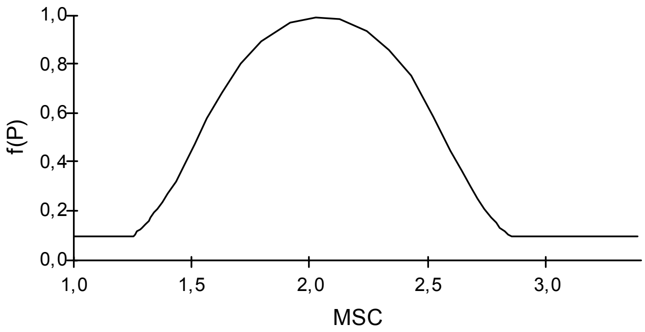

Figure 1. A function implemented in the calculation of daily rate of change in MSC in timothy to count for different rates of change at different developmental stages.

Results and discussion

Assuming that the rate of phenological development was the same during the whole continuum of events from MSC=1 until MSC=3.5, the equation for the daily rate was found to be:

Eq II: $dP = 0.000188\ (T - 3.0)\ (Dl - 5.5)$

$Dl_m = 18$ t

See Figure 2 (lines 1 and 2), for daily rates of change at Løken calculated according to this equation.

Taking the option that the rate differed according to developmental stage, the equation for daily advance appeared to be:

Eq III: $dP = 0.000736\ (T - 3.0)\ (Dl - 5.5)$

$Dl_m = 18$ t

See Figure 2 (lines 3 and 4), for daily rates at Løken calculated according to Eq. III. The rate function *f(P)* (Figure 1) weighting the calculated *dP* was through optimisation found to attain its maximum (1.0) at MSC 2.05 and to have a P_k of 2.2.

Table 1. Coefficients of determination (r^2) for the relationship between calculated and observed MSC at three sites during two years. Two options for the calculation were investigated. The number of observations at each site each year is given in brackets.

	2004		2005	
Site	rate independent of MSC	rate dependent on MSC	rate independent of MSC	rate dependent on MSC
Kvithamar	0.949 (11 obs)	0.931 (11 obs)	0.922 (15 obs)	0.938 (15 obs)
Løken	0.764 (4 obs)	0.999 (4 obs)	0.939 (14 obs)	0.905 (14 obs)
Særheim	0.999 (3 obs)	0.994 (3 obs)	0.940 (13 obs)	0.960 (13 obs)

Both options for calculating the progress of MSC during the growing season worked quite well and predicted the development satisfactorily (Figure 3). Expanding the quantitative relationship with *f(P)*, however, did not improve the goodness of fit between recorded and predicted MSC (Table 1). Still, we intend to include data from 2006 to further sort out whether Eq. II and the connected assumption of independence between rate and phenological stage are valid.

Other suggestions for improvements are to determine the actual interval for MSC for timothy and other species (not starting at exactly 1.0 for any of them), to weight day and night temperatures differently, and to differentiate the influence of day length according to the MSC.

In relation to the decision support tool under development (Bakken *et al*. 2006a), it is our aim, however, to keep the model as simple and robust as possible, and the phenological function will not be expanded unless the gain by doing so is substantial.

We are quite confident that MSC will be the phenological scale for spring growth in our decision support tool, and we are also investigating possible simplifications of the pre-harvest counting and classification of shoots to make the calibration procedure more user friendly.

Whether and how phenological development should be implemented in predictions of yield and quality of regrowths also needs to be further explored, and we have data available to do that.

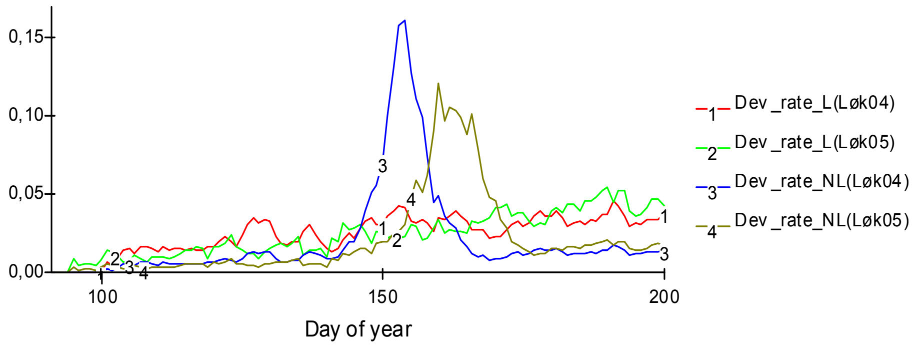

Figure 2. Daily rates of phenological development (*dP*) (d^{-1}) at Løken during two years calculated according to Equations II (Dev_rate_L) and III (Dev_rate_NL).

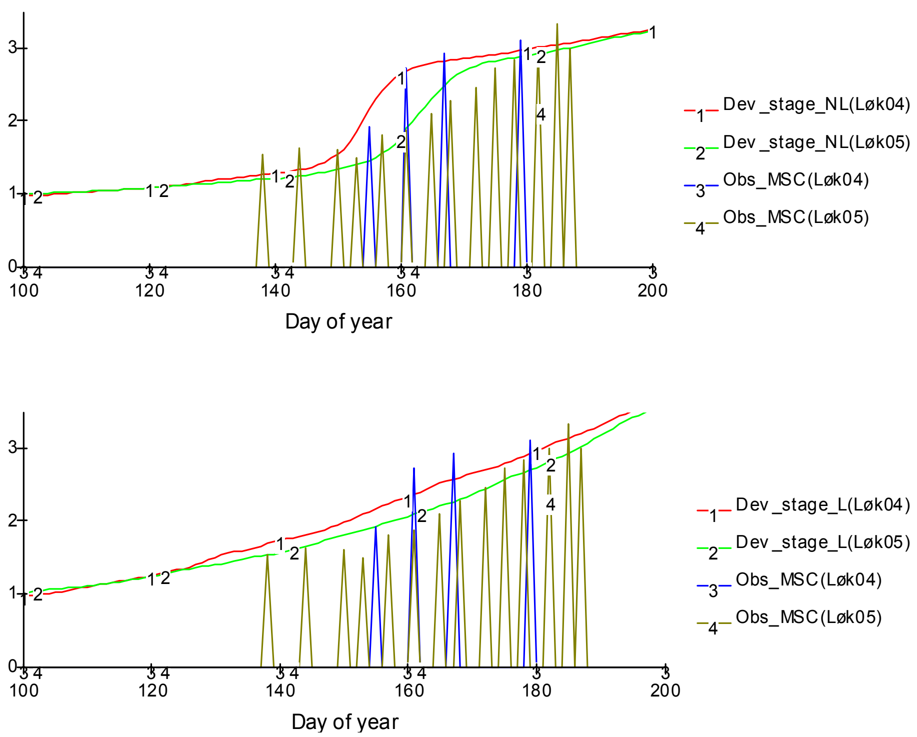

Figure 3. Observed and calculated MSC of timothy swards at Løken during two years (2004 and 2005). The calculations were performed assuming that the rate of change was independent of stage of development (Dev_stage_L) and that it varied according to stage of development (Dev_stage_NL).

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Estimated growth cessation of timothy swards as a basis for regulation of surface application of cattle slurry in autumn

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Introduction

The last legal day for surface application of cattle slurry in autumn was, prior to 2005, the 1st of September for the whole of Norway. Knowing that there is large geographical variation in the duration of the growing season within the country, and intending to delegate to local authorities the regulation of spreading cattle slurry, the Ministry of Food and Agriculture asked the Norwegian Crop Research Institute to contribute by providing the scientific basis for the new locally adapted regulations.

Growth cessation of timothy (*Phleum pratense* L.) sward and nitrogen (N) uptake after the last cut are crucial factors in an assessment of the last day or deadline for surface application. In autumn, the daily growth of a timothy sward decreases, mainly due to lower temperatures and decreasing light levels and day length. Although its net growth gradually levels off, timothy as well as other temperate perennial grasses and legumes do not become true winter dormant. Sward uptake, and assimilation, of N from the last cut until growth cessation is proportional to net production in the same period. Geographically differentiated estimates for the production during this period are consequently also needed to give a sound basis for new regulations for slurry application in autumn.

In the present paper we have outlined how net production and growth cessation in autumn were calculated and presented information on how the results were applied to give suggestions for guidelines for regional legislation and regulations.

Methods

To cover the geographical variation among regions with grass production in Norway, five sites were selected: Holt (north, 69˚39' N 18˚56' E), Kvithamar, (central coast, 63˚28' N 10˚54' E), Storsteigen (central inland, 62˚7' N 10˚37' E), Tomb (south-east, 59˚21' N10˚54' E), and Øksnevad (south-west, 58˚46' N 5˚39' E). Data for soil characteristics and five years of weather measurements, daily means of temperature, relative humidity, and wind speed, and daily sums of global radiation and precipitation were used to estimate daily growth (Bonesmo 1999), and minimum and maximum N content of timothy swards at each site and year (Bonesmo & Bélanger 2002). The main parameters of the simulation model were calibrated to measurements on normal harvest dates over all sites and years.

Table 1. Simulated growth cessation of timothy swards at five sites during five years.

Site	2000	2001	2002	2003	2004	Mean
Holt	21 Sep	20 Sep	15 Sep	15 Sep	8 Sep	16 Sep
Kvithamar	12 Oct	28 Sep	18 Sep	19 Sep	2 Oct	28 Sep
Storsteigen	10 Oct	10 Oct	1 Sep	24 Sep	27 Sep	26 Sep
Tomb	24 Oct	23 Oct	5 Oct	8 Oct	12 Oct	14 Oct
Øksnevad	26 Oct	28 Oct	10 Oct	18 Oct	27 Oct	22 Oct

To map the growth cessation of timothy swards of all Norway we used MODIS satellite data calibrated in the PhenoClim (2005) project. The phenological changes during a season can be studied by changes in the remote sensing-based Normalized Difference Vegetation Index (NDVI) value. The NDVI is defined as: NDVI = (Ch2-Ch1)/(Ch2+Ch1), where Ch1 and Ch2 represent reflectance measured in near infrared and red channels, respectively. The MODIS 16-days NDVI data set with 250m spatial resolutions for the 2000 to 2004 period was used in this study (calibrated standard MOD13Q1 product).

Each site and year involved at least one timothy sward. For each of the timothy swards we calculated the NDVI values for the June to November period each year, and combined with the simulated growth cessation, we determined the NDVI threshold for the end of the growth. These thresholds from MODIS-NDVI data, environmental GIS data, and analysis of how the timothy swards responded in comparison with other land cover types were then used in the GIS modelling of growth cessation of timothy swards for all Norway. Areas with a low NDVI sum for the summer period were interpreted as less vegetated mountain areas and not included in the study.

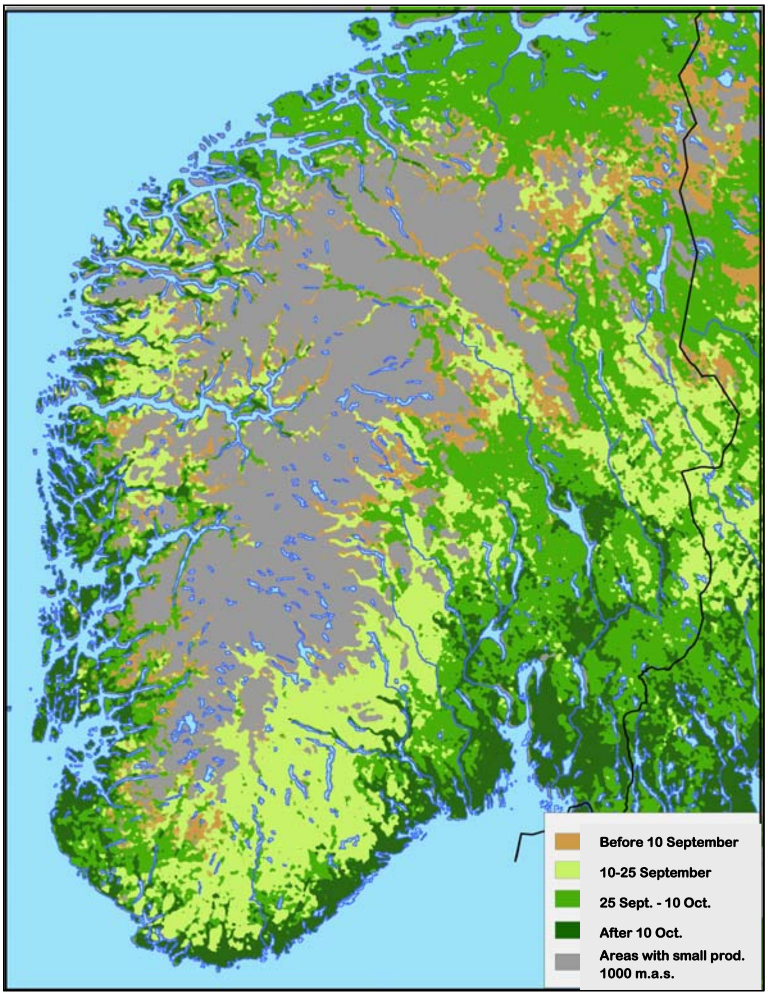

Figure 1. Map of estimated growth cessation of timothy grass in southern Norway based on MODIS- NDVI satellite data from the years 2000 -2004.

Results and discussion

The map of the growth cessation of timothy swards of all Norway, here exemplified with the map of southern Norway (Figure 1), is based on the estimated end of growth (Table 1), GIS data, and NDVI measurements for the 5-year period that we used. The map shows gradients running from north to south, form west to east (ocean gradient), and partly along the altitudinal gradient. It was used slightly differently from the GIS data and the modelling methods for South, Central, and North Norway, and at the overlap there is some lack of coincidence.

In search of recommendations for local deadlines for application of cattle slurry, the final date was related to the simulated growth cessations such that the mean accumulated N uptake of the sward should be 4 g N m^{-2}; e.g. a technical optimisation of final date using the growth and N uptake simulation model under the constraint of 4 g N m^{-2} accumulated in the herbage at the date of growth cessation. Using this procedure we found that as a rule of thumb a recommended final date should be four weeks prior to the growth cessation, as shown on the map (Figure 1). Examples of the final date would then be August 19 at the northern site of Holt and more than a month later, September 24, at the south-western site of Øksnevad (Figure 2).

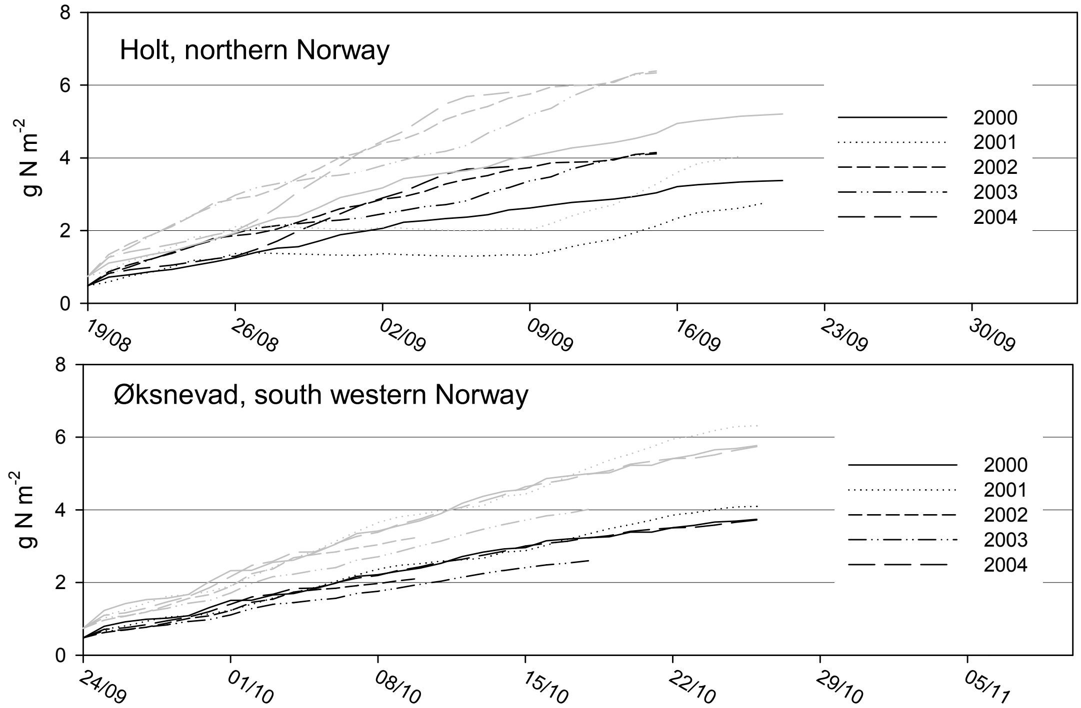

Figure 2. Simulated N content of timothy swards at the sites with the earliest and latest growth cessation after cut at the date locally recommended and practised. Black and grey lines represent minimum and maximum content at the simulated yield levels.

Conclusion

The range for the geographical variation of the date of simulated growth cessation of timothy swards in Norway was about one month. A rule of thumb for what ought to be the final date of surface application of cattle slurry in autumn is four weeks prior to estimated growth cessation, as shown in Figure 1. The use of a simulation model in combination with simple field measurements and satellite data appeared to be a time and cost effective method to solve the task.

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The effect of management and accompanying grasses on the persistence of timothy

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Introduction

Timothy is usually dense in the year after sowing and leaves little space for other grasses and weeds as it grows taller. When cut late, in late July or early August, timothy may remain dominating for several years. Early harvest, around heading, is recommended for feeding productive animals such as lactating cows. Regrowth of timothy is slow and other vegetation gains ground following harvest. Icelandic experiments have shown that timothy in 1st cut is reduced on a dry weight basis by 1.5 percentage units for each week that the harvest is moved forward from a late harvest date, cumulative over years, all fertilizer applied in spring (Hermannsson & Helgadóttir 1991; Helgadóttir & Hermannsson 1991). Other treatment factors were of less importance. Timothy was favoured by early application of fertilizers in one experiment but not in two others. Somewhat less timothy was found following low fertilization rates, N<100 kg ha^{-1}. The most common grass species replacing timothy was smooth meadow grass (*Poa pratensis*), either sown in mixture or volunteering. Common bent grass (*Agrostis capillaris*) competed more strongly when sown and it also tended to replace smooth meadow grass where it invaded.

Timothy is often sown in mixture with other grasses. The purpose may be clean soil surface in order to prevent contamination, or increased regrowth potential and quality. For good quality of the regrowth fertilizer is usually split and a part given right after the 1st harvest. This is expected to favour the competing grasses. Different competing strength of smooth meadow grass varieties is also a factor to consider.

The experiments

Timothy was sown in a 2:1 mixture with the smooth meadow grass variety Lavang in a 2×2×2×3 factorial experiment with three replicates in 1995. The treatments were applied in 1996–1998 and the plots harvested in 1996–1999. The harvest of all plots was sampled for botanical analysis, except in 1996 one half of the plots only. The harvest dates of the 1st and 2nd cuts were 2×2 factorial treatments, arranged on the main plots. The dates of 1st cut were 27–30 June and 15–17 July and dates of the 2nd cut 23–25 August and 6–8 September, mean dates 29 June, 16 July, 24 August and 7 September. The sub-plot treatments were method of fertilization and timothy varieties. Nitrogen was applied at 180 kg ha^{-1}, all in the spring or split 2:1 with 60 kg ha^{-1} applied after 1st cut. The timothy varieties were Adda, Vega and Saga. In 1999 accumulated treatments effects were measured, with 100 kg N ha^{-1} applied in the spring and all plots harvested on 5–6 July.

In a series of three experiments twelve varieties of smooth meadow grass, thereof nine at all sites, were tested over three years in a pure stand in two replicates and in a mixture with Adda timothy, also in two replicates. The nitrogen level was 150 kg ha^{-1}, split application 2:1. Botanical composition was determined for each cut with exceptions at one site.

Results

The first year results from the factorial experiment show the initial direct treatment effects (Table 1). The heading of timothy was estimated on the plots of the late cutting treatment on a 0-10 scale with 10 as full heading, showing significantly later development of Saga than the other two varieties. Interaction effects were nonsignificant except that the splitting of fertilizers had a greater effect on the yield in the 2nd cut following early than late 1st cut. The growth rate was 169 kg DM d^{-1} ha^{-1} between dates of the 1st cut. Vega had initially a weaker stand than the other two varieties. The date of the 2nd cut had little or no effect on yield or persistence of timothy in this experiment and results for this factor are not shown below.

Table 1. Yield, % timothy and heading in the factorial experiment 1996.

	Yield, DM t ha^{-1}			Timothy, %		Heading
Variety	1st cut	2nd cut	total	1st cut	2nd cut	3 July
Adda	7.85	1.38	9.23	95.2	80.8	5.6
Vega	7.92	1.52	9.44	91.2	76.1	5.3
Saga	7.72	1.61	9.33	94.8	87.3	4.5
SED	*0.17*	*0.052*	*0.17*	*0.73*	*1.7*	*0.19*
Nitrogen application						
In spring	7.87	0.92	8.79	93.6	84.7	
Split	7.79	2.08	9.87	93.9	78.0	
SED	*0.14*	*0.042*	*0.14*	*0.57*	*1.4*	
Cutting treatments						
1st cut 27-Jun	6.31	1.94	8.26	92.1	77.0	
1st cut 15-Jul	9.35	1.06	10.41	95.4	85.7	
2nd cut 23-Aug		1.39	9.21		80.1	
2nd cut 6-Sep		1.61	9.46		82.6	
SED	*0.19*	*0.075*	*0.13*		*1.4*	

Timothy was dominant in the first harvest in 1996 but declined gradually with time. Results from the final harvest in 1999 for two way combinations of timothy varieties with the factors date of 1st cut and nitrogen application are shown in Table 2. The standard error of difference (SED) for comparison of the same variety between cutting dates was 5.24. Adda is the most northern of the three varieties and resisted the competition better than the others, especially when cut late. Other interaction effects were nonsignificant. The better adaptation of Adda is also shown by the lower percentage of weeds, the remainder being smooth meadow grass.

Table 2. Percent timothy (SED=2.25 for sub-plots) and weeds in 1999.

	Mean date of 1st cut		N application			
Variety	29-Jun	16-Jul	spring	split	Mean	Weeds
Adda	56.8	73.1	72.5	57.5	65.0	1.6
Vega	49.3	59.6	61.3	47.6	54.4	2.2
Saga	51.6	54.7	61.1	45.1	53.1	2.3
Mean	52.6	62.5	65.0	50.0		

In this experiment the effect of early cutting on timothy was 2.2 % decline per week which fits well to the earlier results. The combined estimate for all experiments is 1.7 % per week if calculated through the origin.

Split application of nitrogen reduced timothy in the sward by 5.0 % units per year as compared to all N applied in spring. The difference was 5.1 and 11.1 % for the 1st cut in 1997 and 1998, respectively, so that the trend was approximately linear with time.

Table 3. DM yield in 1999, t ha^{-1}.

Mean date of 1st cut		N application		Varieties	
29 June	3.69	Spring	3.83	Adda	3.85
16 July	3.86	Split	3.72	Vega	3.79
				Saga	3.67
SED	*0.10*		*0.0039*		*0.0048*

The residual treatment effects on yield in 1999 were small, although statistically significant for the sub-plot factors nitrogen application and varieties (Table 3), and were related to the differences in percentage of timothy. Replacing nitrogen application by timothy % as a term in the linear model gives the effect 0.065±0.022 t ha^{-1} for a 10 % increase in timothy. This may be underestimation as some residual effect of split nitrogen application can be expected.

In Table 4 results from variety trials with smooth meadow grass are summarized as means over all varieties in a pure stand and in mixture with timothy, respectively. Timothy was dominating in the mixtures when first harvested and the reduction of timothy % with time reflected the combined effect of early cut (July 3) and split nitrogen application. At two sites with soils rich in organic matter and rather poor physical soil conditions the mixture with timothy gave more yield than pure meadow grass in the first year. Adapted timothy varieties do rather well under these circumstances and the grass growth helps to dry out the soil and improve the conditions. At Korpa conditions were good with substantial mineralization of nitrogen after soil cultivation in 1999. The results indicate that smooth meadow grass was better able than timothy to take advantage of these conditions for luxurious growth. Earlier results have shown that nitrogen applied late in the summer is absorbed by grasses and stored over the winter and is available for grass growth the following spring. Timothy appears to be less able to carry over nitrogen effects than grasses like smooth meadow grass and leaves more nitrate in the soil late in autumn (Björnsson 1998a,b), although this effect alone is perhaps not sufficient to explain the higher yield of meadow grass in 2000.

Table 4. Mean annual yield in smooth meadow grass variety trials in pure and mixed stand, distribution of yield on cuts, and timothy % in mixed stand.

		DM t ha^{-1}		Yield in 2nd cut, %		Timothy %	
Site	Year	pure	mixed	pure	mixed	1st cut	2nd cut
Korpa	2000	9.0	7.2	37	29	95	71
	2001	8.3	7.3	33	27	79	51
	2002	6.8	6.9	25	22	62	38
Stóra-Ármót	2000	5.4	7.0	41	17	93	69
	2001	6.5	6.2	45	30	67	57
	2002	6.9	6.7	28	20	68	40
Hvanneyri	2000	5.6	6.5	70	41	80	
	2001	8.5	7.9	50	38	67	
	2002	6.1	6.0	34	34		

The percentage of timothy differed among smooth meadow grass varieties, as shown in Figure 1, in relation to yield of meadow grass in a pure stand. Results for timothy are the means of both cuts in 2002 at Korpa and Stóra-Ármót and the 1st cut in 2001 at Hvanneyri. Yield in pure stands is the average over three years. SED = 5.8 and 0.30 for timothy % and yield respectively for varieties tested at three sites (diagram to the left), the interaction with sites used as an estimate of error.

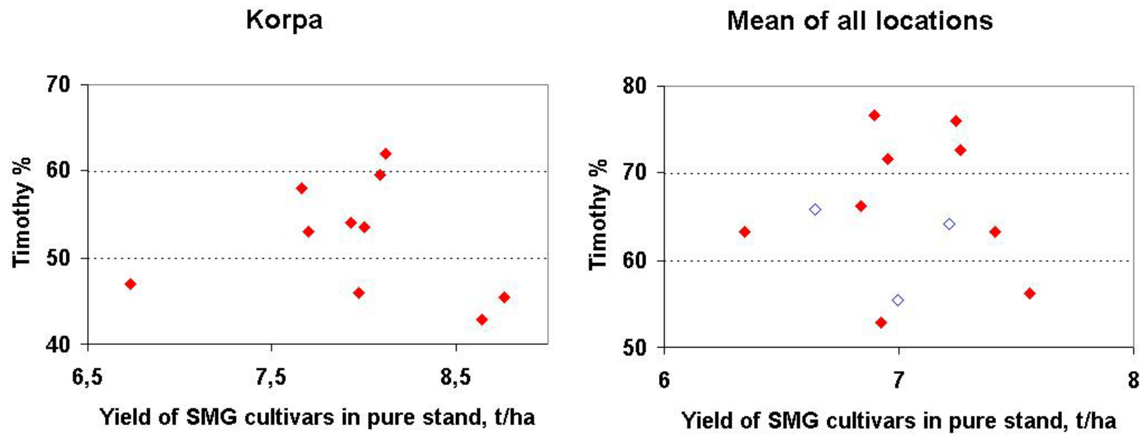

Figure 1. Final timothy % in relation to yield of smooth meadow grass varieties, Korpa (left) and all sites (right). Open symbols indicate varieties tested at one or two sites.

The diagrams show appreciable significantly different effects of varieties on the persistence of timothy. Excluding the lowest yielding variety, there was a tendency at Korpa for high yielding varieties to be more competitive with the timothy than the low yielding ones.

On the role of nitrogen

Timothy differs from native grasses in its nitrogen budget. These are better able to use nitrogen reserves to begin spring growth if they are well supplied in the previous autumn or late summer. Early application and N ≥ 100 kg ha^{-1} may favour timothy in the competition.

Occasionally timothy in mixture becomes pale, a symptom of nitrogen deficiency. This was observed in 1980 at the Skriðuklaustur experiment station for timothy in a mixture with an Icelandic selection of smooth meadow grass but not in three other treatments with timothy in a mixture with smooth meadow grass or red fescue. Weak symptoms were also observed on plots with a low timothy percentage in the factorial experiment reported here. Nitrogen was analysed in mixed herbage and in the sorted samples from selected plots. No relationship was found between nitrogen in timothy and the percentage of timothy in the sample, but a higher nitrogen concentration was found in smooth meadow grass on plots with timothy dominating. Timothy lines have been found to differ in their ability to use soil nitrogen and this may be of some significance for their competing ability (Björnsson & Helgadóttir 2000).

Summary

Timothy is a rather new species in Icelandic agriculture and is preferred to the native grasses. The most important factor determining the persistence of timothy in a sward, other than variety, is harvest date. If cut late, three to four weeks after heading, timothy varieties of northern origin may remain dominating in Icelandic swards for a long time. The percentage of timothy in first harvest is irreversibly reduced by 1.7 percentage units on average for each week that the harvest is moved forward, cumulative over years. Timothy is favoured by good timing of fertilization in spring. Split application favours grasses with greater regrowth potential and it accelerated the retreat of timothy by 5% y^{-1} independently of cutting date or timothy variety. Smooth meadow grass is often sown in a mixture with timothy for improved

sward and regrowth. Meadow grass varieties compete differently and the highest yielding ones are perhaps not the best for use in a mixture with timothy.

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Fluctuations in the timothy population in mixed swards according to harvesting regime

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Introduction

The growing season in most of the districts with dairy and meat production in Norway is rather short, lasting from 150 to 200 days with a mean temperature above 5°C. Still, two cuts per season are often not sufficient to obtain high silage quality in both of them, irrespective of species composition. Harvesting regimes with three cuts per season with a first cut at a rather early developmental stage might, however, be a too intensive option, both for the farmer and the timothy.

It is well documented that timothy (*Phleum pratense*) does not sustain frequent harvests as well as meadow fescue does (Østrem & Øyen 1985; Grønnerød 1988). In mixed and intensively managed swards, meadow fescue (*Festuca pratensis*), by time, constitutes an increasing proportion of the yield. This might be related to the more synchronous generative development in timothy, causing a low proportion of non-elongated tillers at harvest and few intact meristems for regrowth afterwards. However, Bonesmo and Skjelvåg (2000) have shown that there are small differences in regrowth rates between the two species when first cuts are taken from leaf stage until early heading.

In the investigation presented here, we have studied the timothy population in mixed swards with red clover (*Trifolium pratense*) and meadow fescue under different two- and three-cut regimes in which most first cuts were taken at rather early developmental stages. Different second and third cuts were timed according to heat sum units and precisely documented according to Mean Stage by Count (MSC) (Moore *et al.* 1991). We were interested to know how the competitiveness of timothy versus the other species was related both to the developmental stage at first cut and the timing and number of successive cuts. The presentation also addresses the question of how important timothy persistence and dominance are for the quality of first and later cuts.

Methods

Field trials with six or seven harvesting regimes combined with two levels of N supply (120 and 240 kg N ha^{-1}) were conducted in leys with *Phleum pratense* ('Grindstad'/'Vega'), *Festuca pratensis* ('Fure') and *Trifolium pratense* ('Nordi') (1:1:0.5 w/w/w of seeds at establishment) at three locations in Norway (Table 1). The same regimes have been applied on the same plots for three years (2004-2006). Data from four regimes at each site are presented here. The botanical composition of the yield at the different cuts was determined both by visual and subjective evaluations of all single plots, and by sorting and later drying of yield samples (one sample for each combination of regime and level of N supply). No results of statistical treatments of the data are presented. Those findings commented on, are, however, validated both by sorting and independent evaluations by two persons.

Precise registrations of phenological stage of development were undertaken at all harvests for all species according to Moore *et al.* (1991).

Table 1. Description of locations and treatments of 3-year field trials in mixed swards with timothy, meadow fescue and red clover. First cuts were timed according to the developmental stage of timothy. The growing season relates to 1961-1990 normal values and a base temperature of 5°C. The base temperature for the determination of harvesting dates is 0°C. The short form "elong" stands for elongation and "head" for heading.

Location	Number of days and heat sum in growing season	Harvesting regimes according to number and timing of cuts			
		regime 1	regime 2	regime 3	regime 4
Særheim 58°47'N	209 days, 1251 day°	1st at stem elong 2nd 600 d° later 3rd at 20 Sept	1st at stem elong 2nd 750 d° later 3rd at 20 Sept	1st at early head 2nd 600 d° later 3rd at 20 Sept	1st at early head 2nd 750 d° later 3rd at 20 Sept
Løken 61°7'N	149 days, 786 day°	1st at stem elong 2nd 400 d° later 3rd at 30 Aug	1st at early head 2nd 400 d° later 3rd at 30 Aug	1st at early head 2nd 600 d° later 3rd at 30 Aug	1st at full head 2nd at 30 Aug
Kvithamar 63°30'N	182 days, 1064 day°	1st at stem elong 2nd 500 d° later 3rd at 5 Sept	1st at stem elong 2nd 700 d° later 3rd at 5 Sept	1st at full head 2nd 500 d° later 3rd at 5 Sept	1st at full head 2nd at 5 Sept

Results and discussion

The proportion of timothy in the swards when the treatments started varied between the three sites (Tables 2a-c). It was highest at Løken and lowest at Kvithamar.

Treatments causing a decline in the timothy population from the first cut the first year to the first cut the second year, were the two regimes with first cuts as late as early heading at Særheim, all regimes with three cuts (i.e. with first cuts before full heading) at Løken, and all three-cut regimes at Kvithamar. The decline had already started during the first growing season and was probably not related to winter mortality. At Kvithamar, meadow fescue was the most competitive or aggressive species, whereas at Løken and Særheim red clover was more, or as least as aggressive, especially at low levels of N supply (data not shown). The second year, the proportion of timothy was higher at the higher than at the lower level of N supply, irrespective of harvesting regime.

From this it might be interpreted that late first cuts (here at full heading) are not sufficient alone to ensure a high proportion of timothy in the sward. When such a cut was followed by two cuts or an early second cut the same season, the proportion of the species declined (Table 2c). In contrast to meadow fescue, timothy has no demand for short days or low temperature for the induction of generative development (Heide 1989), and elongated/generative shoots occur also in regrowths, irrespective of stage at first cut. This might increase its competitiveness if it is allowed to regrow for such a long time that the new and possibly elongated tillers emerging from the base contribute to a closure of an erect canopy above the vegetative and lower stand of fescue. At early cuts of regrowths, however, this potential will not be realized and timothy might rather be retarded (relative to meadow fescue) by another removal of elevated meristems and buds for the second time the same season. In other words, the timothy needs time to develop high and dense canopies to dominate the regrowing sward.

Take for instance regimes 1 and 2 at Kvithamar in 2005. At the early second cut (regime 1) the MSC of timothy was 2.1 whereas it was 2.8 in the late second cut in regime 2 performed 200 day° later. A regrowth after the earliest one might benefit from a higher proportion of non-elongated tillers (expressed as a MSC of 2.1 versus 2.8). Still, when cut at this stage its hypothetical potential as a "shader" to meadow fescue and red clover (MSC of 1.3 and 1.8 at this stage) would not have yet been fully realized. Although timothy would have suffered more for the loss of meristems on elongated tillers in the later second cut, this was probably outweighed by the chance to dominate the other species before the cut.

Table 2a. The proportion (% of dry yield) of timothy (tim), meadow fescue (fesc) and red clover (clov) at different harvests in a field trial in mixed swards at Særheim. The data represent means for two levels of N supply. See Table 1 for details of harvesting regimes.

	1st st cut 1st year			Last cut 1st year			1st cut 2nd year		
Harvesting regime	tim	fesc	clov	tim	fesc	clov	tim	fesc	clov
1. 1st cut at stem elongation	60	15	20	40	30	35	65	5	30
2. 1st cut at stem elongation	60	15	20	40	25	35	60	10	30
3. 1st cut at early heading	70	20	10	35	35	30	40	15	45
4. 1st cut at early heading	70	20	10	35	40	25	35	35	30

Table 2b. The proportion (% of dry yield) of timothy (tim), meadow fescue (fesc) and red clover (clov) at different harvests in a field trial in mixed swards at Løken. The data represent means for two levels of N supply. See Table 1 for details of harvesting regimes.

	1st st cut 1st year			Last cut 1st year [1]			1st cut 2nd year		
Harvesting regime	tim	fesc	clov	tim	fesc	clov	tim	fesc	clov
1. 1st cut at stem elongation	80	10	5	55	25	15	55	15	30
2. 1st cut at early heading	80	10	5	50	30	20	50	15	30
3. 1st cut at early heading	80	10	5	55	30	15	75	10	10
4. 1st cut at full heading	80	10	5	70	20	10	85	5	10

[1] Determined by visual evaluation

Table 2c. The proportion (% of dry yield) of timothy (tim), meadow fescue (fesc) and red clover (clov) at different harvests in a field trial in mixed swards at Kvithamar. The data represent means for two levels of N supply. See Table 1 for details of harvesting regimes.

	1st st cut 1st year			Last cut 1st year			1st cut 2nd year		
Harvesting regime	tim	fesc	clov	tim	fesc	clov	tim	fesc	clov
1. 1st cut at stem elongation	55	25	20	10	25	65	30	55	20
2. 1st cut at stem elongation	55	25	20	15	30	55	25	60	15
3. 1st cut at full heading	50	35	15	10	45	50	30	50	15
4. 1st cut at full heading	50	35	15	50	15	35	65	35	5

It also seems that cuts at stem elongation do not imply any more severe stress to timothy (relative to the other species) than cuts at early heading do. This is in accordance with the findings of Bonesmo and Skjelvåg (2000), and might well be related to the structure of the sward on these two occasions.

According to the present results, a decline in the timothy population would not cause a decline in quality of the harvested yield if the species is replaced by meadow fescue. The energy content of fescue at Kvithamar in 2004 was as least as high as in timothy at all harvests of all regimes (Table 3). The energy content of red clover was also at least as high as in timothy at all first and second cuts.

Table 3. Energy content (Milk feed units, FE_m, per kg DM) as analysed by Near Infra Red Spectroscopy of timothy (tim), meadow fescue (fesc) and red clover (clov) harvested at Kvithamar in 2004. The data are means for two levels of N supply. See Table 1 for details of harvesting regimes.

	1st cut			2nd cut			3rd cut		
Harvesting regime	tim	fesc	clov	tim	fesc	clov	tim	fesc	clov
1. 1st cut at stem elongation	0.97	1.00	1.00	0.86	0.90	0.92	0.88	0.91	0.80
2. 1st cut at stem elongation	0.97	1.00	1.00	0.78	0.78	0.79	0.91	0.93	0.88
3. 1st cut at full heading	0.80	0.85	0.89	0.87	0.88	0.90	0.91	0.93	0.86
4. 1st cut at full heading	0.80	0.85	0.89	0.72	0.85	0.73	No 3rd cut	No 3rd cut	No 3rd cut

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Improving seed production of organic timothy (*Phleum pratense*) - preliminary results of an advisory campaign in Sweden

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Summary

The production of organic grass and clover seed has increased significantly in Sweden during recent years, with timothy being the most important crop. The growing area of organic timothy for seed production has increased from 48 ha in 2000 to an estimated 1,271 ha in 2006. Sweden is now by far the world's largest producer of organic timothy seed. When the growing area of organic timothy increased, problems emerged due to the inexperience of growers and to lack of knowledge about growing techniques. Yields were unacceptably low, mainly because of unsatisfactory establishment of the crop, weed problems (especially Scentless Mayweed, *Tripleurospermum perforatum*) and ignorance about appropriate harvesting methods. In October 2004, the seed companies and representatives from the Swedish advisory service therefore asked the Swedish Board of Agriculture to initiate an advisory campaign to improve the stability and quality of organic ley seed production. The campaign started in February 2005 and included newsletters, new information material, a website (www.sjv.se/ekovallfro), field days, seminars and research and development projects.

In March 2006 a survey was carried out on whether yields in organic ley seed production had improved. This survey showed that the yield of organic timothy seed increased from 247 kg ha^{-1} in 2004 to 467 kg ha^{-1} in 2005. A questionnaire after harvest in 2005, which evaluated the first year of the campaign, showed that the campaign was only partly responsible for the yield increase. The questionnaire was answered by 88% of Swedish organic timothy producers, 14% of whom were convinced that the campaign had given them a higher yield in 2005. A further 48% expected their yield in 2006 to be higher because of the campaign. The campaign also affected the timothy seed producers in other ways: 18% experienced a clear improvement in the establishment of their timothy, 28% achieved better weed control and 29% improved their harvesting technique. The campaign is continuing in 2006.

Improvement in organic ley seed production in Sweden

The growing area of organic ley seed has increased dramatically since 2002 (Table 1). The main reason for the increase was a new set of rules, partly concerning organic ley seed mixtures, which was approved by the Swedish Board of Agriculture in the autumn of 2002 and led to the establishment of a functioning market for organic ley seed.

Table 1. Area (ha) of organic ley seed production in Sweden, 2000-2006

Ley species	2000	2001	2002	2003	2004	2005	2006
Timothy (*Phleum pratense*)	48	107	197	282	559	862	1271
Meadow fescue (*Festuca pratensis)*	6	10	98	96	205	412	568
Red clover (*Trifolium pratense)*	45	54	185	326	468	588	666
White clover (*Trifolium repens*)	5	19	21	43	135	230	283
Alsike clover (*Trifolium hybridum)*	0	0	0	20	29	33	30
Total area	104	190	501	767	1397	2125	2818

Sweden is now the world's largest producer of organic ley seed measured in growing area, and second only to Denmark concerning total yield. The Swedish Board of Agriculture supports the development of organic ley seed production because:

a) According to EU legislation, organic farmers must use organic seed.

b) Ley seed is traditionally grown in the agricultural areas with the most intensive production in the south of Sweden. To reach the national environmental goal of a 'Toxin-free environment', more organic farming is needed in these areas.

c) Sweden is believed to have good climatic conditions for organic ley seed production, with fewer problems with fungal diseases than central Europe and fewer problems with certain pests (e.g. *Apion duchorum*) than Denmark.

Seed yields in timothy

Timothy is the most important organic ley seed crop in Sweden and several different cultivars are grown (Figure 1). Since 2000, 48 farmers have grown cv. Alexander, 35 farmers have grown cv. Grindstad and 12 farmers have grown cv. Jonatan. Cvs. Lischka, Kämpe II, Motim and Vega have only been grown by one or two farmers, so Figure 1 does not give a reliable picture of the potential of these cultivars in organic farming.

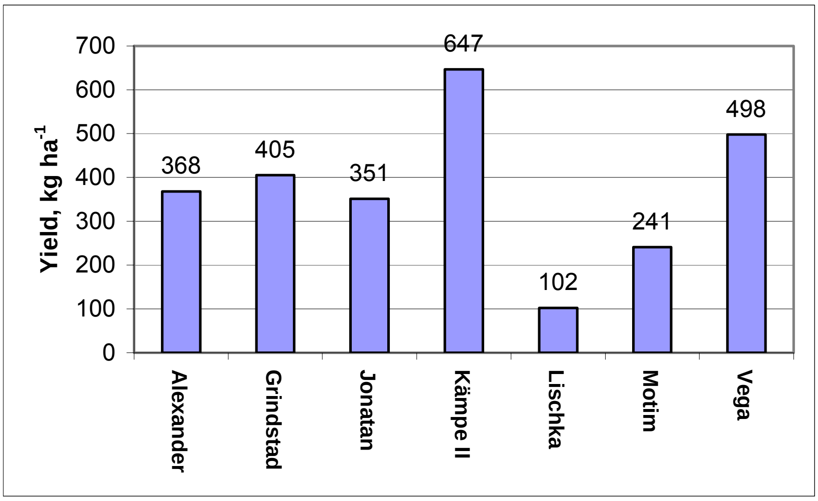

Figure 1. Average seed yield (kg ha^{-1}) of different cultivars of organic timothy in Sweden, 2000-2005.

Cv. Grindstad is regarded as more difficult to grow than other cultivars and occasional farmers have been paid an additional premium to grow this cultivar in Norway and Sweden. However, as Figure 1 shows, the average yield of Grindstad is in fact better than that of the other two major cultivars – Alexander and Jonatan.

As the growing area increased, there was a clear tendency from 2000 to 2004 for the average seed yield to decrease year after year due to the fact that new growers lacked experience and to lack of knowledge about the appropriate growing technique (Figure 2). That was the background for the organic ley seed campaign initiated in February 2005. The seed yield increased 89 % from 2004 to 2005 partly because of the campaign and partly because of exceptionally good climatic conditions during pollination and harvest. In conventional farming the yield increased 40% between 2004 and 2005 from 420 kg ha^{-1} to 590 kg ha^{-1}.

Results from the first questionnaire – January 2005

A total of 22 farmers (79%) with organic timothy responded to the first questionnaire, which produced some interesting results concerning weed problems and harvesting techniques.

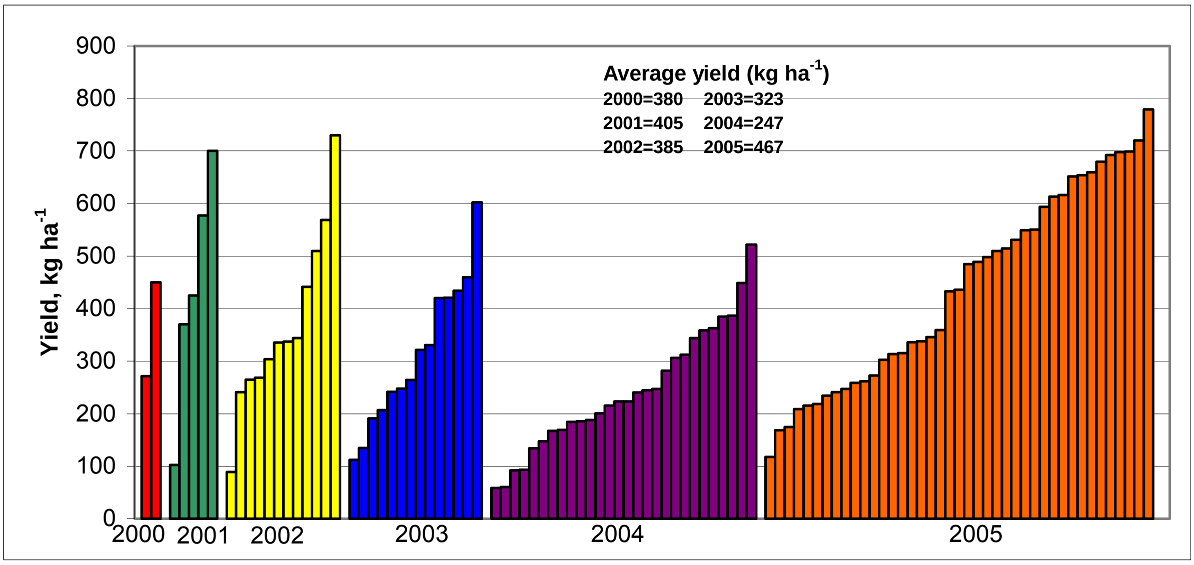

Figure 2. Seed yield (kg ha^{-1}) of organic timothy in Sweden, 2000-2005. Each bar represents an individual farmer (Larsson & Pedersen 2006).

Weeds

The organic ley seed farmers were asked which three weeds they considered the greatest problem. As shown in Table 2, Scentless Mayweed and perennial weeds were seen as major obstacles to achieving high yields. The number shows how many farmers of the total of 22 respondents regarded the specific weed as one of the three major weeds in organic timothy production.

Table 2. Farmers' evaluation of the most important weeds in organic timothy production in Sweden (Pedersen 2005a).

	Number of farmers
Scentless Mayweed (*Tripleurospermum perforatum*)	20
Common Couch-grass (*Elymus repens*)	13
Creeeping Thistle (*Cirsium arvense*)	8
Curled Dock (*Rumex crispus*)	3
Common Orache (*Atriplex patula*)	3

As Scentless Mayweed was seen as the major weed problem in red clover, and also in white clover and meadow fescue, the Swedish Board of Agriculture produced a technical leaflet that was sent to all organic ley seed producers (Dock Gustavsson 2005). The main information in the leaflet was that there are two phenotypes of Scentless Mayweed in Sweden. One type grows in spring and dies in the following autumn, while the other type grows in late summer and survives the winter. It is only the latter type that gives problems in organic timothy. The 'spring' phenotype dies when the season turns cold within the harvest year when the organic ley seed crop is established and as the ley seed crop is not ploughed or harrowed in the following spring, no more plants of this phenotype develop. Weed harrowing before sowing of the organic seed crop therefore has no positive effect on the amount of Scentless Mayweed in the following year. In fact, it is often counterproductive, as weed harrowing dries out the surface of the soil, thereby making the establishment of the ley seed more uncertain. Weak establishment provides more opportunity for Scentless Mayweed and Curled Dock to infest the field in late summer and autumn. As weed harrowing before establishment was standard practice before the organic ley seed campaign, this new information was a breakthrough.

Of the farmers with organic timothy seed production responding to the questionnaire, 32% had problems with white or alsike clover. The seeds of these clovers are about the same size as timothy seed and fields are rejected by the seed companies every year because of cross-contamination. The main way to cope with this problem is to harvest directly and leave a high stubble.

Harvesting technique

Table 3 shows that organic timothy producers who harvested timothy in swathes got a much higher yield and an easier harvest compared to the farmers who harvested direct.

Table 3. The influence of harvesting technique on the average yield (kg ha^{-1}) of organic timothy in Sweden in 2004 and farmers' evaluation of the difficulty of harvest (1 = very difficult, 5 = not difficult at all) (Pedersen 2005a).

Direct harvesting		Swathe harvesting		Harvesting difficulty score (1-5)	
yield, kg ha^{-1}	no. of farmers	yield kg ha^{-1}	no. of farmers	direct	Swathe
248	13	409	9	3.1	4.2

Results from the second questionnaire

All organic timothy seed producers were asked to evaluate the organic ley seed campaign in November 2005. The questionnaire was answered by 88% of Swedish organic timothy producers (36 farmers). As Table 4 shows, the campaign already exerted great influence on growing techniques and yield (expectations). Fourteen percent of the farmers were convinced that it was thanks to the campaign that they had a higher yield in 2005 and almost half of the farmers believed that they will get a higher yield in 2006 thanks to the activities of the campaign. In all, 18% of the timothy farmers had better crop establishment, 28% had fewer problems with weeds and 29% had a better harvesting technique because of the campaign. As the first questionnaire revealed that only one timothy farmer had problems with pests (wild boars), it is not surprising that only a very few thought that the campaign had led to fewer problems in this regard. More than 50 % of the farmers established contact with other ley seed farmers with whom they can exchange experiences.

The farmers were generally happy about the different activities in the campaign. The newsletters that were sent 5 times per season directly to the relevant group of farmers (clover seed producers or grass seed producers) were the most popular aspect. Of the timothy farmers responding to the questionnaire, 78% gave the newsletters 4 or 5 on a scale from 1 (poor) to 5 (excellent). The field days, study trips, etc. were also popular but this kind of activity only attracted 47% of the timothy farmers. However, 26% of the timothy producers were large consumers and participated in 3 or more field days during 2005. Only 19% had used the website and even fewer (6%) thought that the website was among the two most important activities in the organic ley seed campaign.

Table 4. Response of timothy farmers to different claims about the organic ley seed campaign, (Pedersen 2005b)

Effect of the campaign:	(Disagree completely) 1	2	3	4	(Agree completely) 5
I had higher yield in 2005	25 %	25 %	36 %	14 %	0 %
I expect to get higher yield in 2006	15 %	15 %	21 %	39 %	9 %
I had better establishment of the ley seed crop	26 %	15 %	41 %	18 %	0 %
I had better weed control	22 %	13 %	38 %	22 %	6 %
I had fewer problems with pests	39 %	19 %	35 %	6 %	0 %
I had a better harvesting technique	23 %	13 %	35 %	19 %	10 %
I established contact with other farmers with whom I can exchange experiences	19 %	6 %	22 %	41 %	13 %

Discussion

The results show that the ongoing advisory campaign has had a significant effect on the yield and growing technique of organic timothy in Sweden. The co-operation between advisory services, seed companies and public authorities has led to a rapid increase in the growing area without jeopardizing the quality and stability of the production. The evaluation of the campaign highlights the fact that the information channels of an advisory campaign have to be carefully chosen. As most organic ley seed producers are large-scale, well-educated and specialized farmers, we initially assumed that communication via the internet would be the best way to spread information. However, old fashioned direct communication by mail was by far the most popular advisory channel among the farmers, while communication via the website so far has been a failure.

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Oral presentations: Feed quality

Sláttuvísa (3)

Glymur ljárinn, gaman!
grundin þýtur undir,
hreifir sig í hófi
hrífan létt mér ettir,
heft er hönd á skafti,
höndin ljósrar drósar.
Eltu! áfram haltu!
ekki nær mér, kæra!

Mowing Song (3)

Slashing, stripping, swashing,
sweeping, he goes reaping,
scythe is swishing blithely.
Slow, behind the mower,
walks a woman raking ---
watch your distance, mistress!
not too near me, darling ---
near my vicious whishing!

Digestibility of timothy

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Introduction

Timothy (*Phleum pratense*) is widely grown for forage in the temperate regions of Europe and North America. Timothy is winter hardy, high yielding and gives fodder with good feeding qualities. This abstract gives a short presentation of factors affecting digestibility of timothy and is based on review of the literature as well as my own results.

Cell wall and digestibility

The cellular content of forage plants is almost totally digestible, but there is great variation in cell wall digestibility (Van Soest 1967). The digestibility of forage plants depends, therefore, mainly on the cellular content and the digestibility of the cell wall. The main components in the cell wall are cellulose, hemicellulose and lignin. Cellulose in young grasses is almost completely digested by ruminants, but lignification decreases digestibility with increasing maturation. Hemicellulose is composed of a mixture of different polymers which vary in digestibility, whereas lignin is resistant to rumen fermentation.

The proportion of cell wall increases as the development of plants goes on. It is known that digestibility of stems declines more quickly than that of leaves (Pritchard *et al.* 1963, Terry & Tilley 1964). Because of this plants with a high stem proportion are expected to decline faster in digestibility.

Factors affecting decline in digestibility

Time

The dry matter yield of grasses increases with time up to a certain level, while crude protein content and digestibility reach maximum very early in the growth period and then decreases with time. The rate of decline in digestibility with time varies a great deal and is dependent on many factors, of which temperature is most important. In a literature review for timothy, based on 69 experimental years from different countries, the daily decline of digestibility varied between 0.25−0.69 per cent units day^{-1} (Thorvaldsson & Andersson 1986). Many other studies published after that gave results within this range (Thorvaldsson & Björnsson 1990, Bélanger & McQueen 1998). However, results from Greenland were a little below 0.25 (Thorvaldsson *et al.* 2000).

Some studies show almost a linear decline in digestibility, others do not. To some extent this depends on the length of the observation period, it is more likely to find deviations if observations are done over a long period. Studies from Sweden show a little more rapid decline of digestibility around heading, whereas two weeks later the rate is lower than before heading (Thorvaldsson & Andersson 1986). It is common to see a little decrease in the decline of digestibility late in the growth period.

The decline in digestibility is much slower in the second crop than in the first one. Results from Northern Sweden (35 experiment years) show an average decline of 0.50 per cent units in the first crop but a decline of 0.17 in the second crop (Thorvaldsson & Andersson 1986). In a Canadian study the decline was 0.44 and 0.29 for the first and second crop respectively, results from one year for each crop (Bélanger & McQueen 1998).

Temperature

The temperature effects on decline in digestibility are both direct, by affecting the cell wall digestibility (Deinum & Dirven 1976, Moir *et al.* 1977), and indirect, by modifying phenological development (Smith & Jewiss 1966, Dirven & Deinum 1977, Ford *et al.* 1979).

However, it is not enough to know that temperature affects digestibility and cell wall content. We need to quantify these effects. The effect of temperature on digestibility is often estimated in growth chambers but outdoor experiments can also be used for this purpose together with meteorological data. Several outdoor experiments have been used in Iceland and Sweden to estimate the temperature effects. In such analyses it is important to isolate the temperature effects from other affecting factors such as time and other climatic factors. The temperature effects are shown in Table 1 together with results from growth chamber experiments. Most of the temperature coefficients are around 0.05, which means that a one degree increase in temperature will increase the rate of decline in digestibility by 0.05 per cent units day^{-1}. The coefficient in the Icelandic data was a little higher but the error of the estimate was also higher. One of the growth chamber experiments gave a lower coefficient. In that experiment, the plants remained at the vegetative stage during the experimental period. Indications of smaller effects of temperature on young plants were also found in Sweden (Thorvaldsson 1987). Indication of slightly smaller effects for each degree at very low temperatures than at high was found in the growth chamber experiments.

The average decline in digestibility of timothy in Iceland was 0.34 per cent units day^{-1} (Thorvaldsson & Björnsson 1990) while the decline in Northern Sweden was 0.49 per cent units, the difference being 0.15 units. During these observation periods the average temperature in Iceland was 10.3°C but 13.9°C in Sweden, the difference being 3.6°C. Applying the coefficient 0.05 to the difference in temperature (3.6 x 0.05) we get 0.18 per cent units which is very close to the observed difference (0.15). According to this, the difference in decline of digestibility between Iceland and Sweden can to a great extent be explained by difference in temperature.

Table 1. Effects of each degree of temperature on digestibility of timothy. Unit = digestibility % dry matter (organic matter in Sweden).

Location	Number of experiment years	Temperature coefficient	References
Northern Sweden			
First cut	36	0.049 ± 0.011	
Second cut	36	0.047 ± 0.011	(Thorvaldsson 1987)
Central Sweden	3	0.058 ± 0.026	(Thorvaldsson & Fagerberg,1988)
Iceland	60	0.086 ± 0.028	(Thorvaldsson & Björnsson 1990)
Greenland, Iceland and Faroe Islands	8	0.048 ± 0.016	(Thorvaldsson *et al*. 2000)
Growth chamber	1	0.051 ± 0.011	(Thorvaldsson 1992)
Growth chamber	1	0.033	(Unpublished)

Radiation

Increased light intensity stimulates photosynthesis and dry matter production. Light intensity influences forage quality, partly through its effect on morphological development (Deinum & Dirven 1972) and partly by its direct effects. High light intensity has a positive effect on the content of water-soluble carbohydrates (Alberda 1965, Deinum 1966) and thereby improves digestibility (Deinum *et al.* 1968). These effects become greater as the supply of nitrogen decreases, as some energy is required for protein formation (Deinum 1971).

In the Icelandic and Swedish calculations, radiation was one of the weather parameters. No significant effect of radiation on decline of digestibility was found except in the second crop in Northern Sweden. For each 1 cal cm^{-2} increase in radiation day^{-1}, the daily decline decreased by 0.0004 – 0.0007 per cent units. The reason for effects in the second crop but not in the first one could be the lower level of radiation during this period. The days are very long in June at these locations.

Nitrogen

The effect of nitrogen fertilizer on digestibility is small and variable. Wilson (1982) surveyed 80 references and found an equal distribution of positive, nil and negative effects of nitrogen on dry matter digestibility of grasses. Thorvaldsson & Andersson (1986) got similar results from 10 references. Wilson considers that the ultimate effect on digestibility depends on the balance between the beneficial and detrimental effects of nitrogen on development and tissue composition. An increase in digestibility due to nitrogen seems to be more common in tropical than in temperate grasses (Wilson 1973).

Results from Northern Sweden show a little faster decline in digestibility at high N levels than at low ones, both in the first and second crop. Bélanger & McQueen (1998) found that plots with limited N did not have as high digestibility at early growth stages as plots fertilized with N and the decline in digestibility was slower.

Time of fertilization also influences the decline in digestibility. Björnsson & Hermannsson (1983) found that late fertilization in spring reduced the decline in digestibility.

Soil moisture

Wilson (1982) surveyed the literature on the effects of moisture stress on the digestibility of herbage dry matter. Most of these results show that low soil moisture has either no effect on digestibility or increases it. In the Icelandic and Swedish investigations, no significant effect of soil moisture on decline in digestibility was found.

Genetic factors

A difference in digestibility of different timothy varieties and genotypes have been reported (Berg & Hill 1983, Surprenant *et al.* 1990, Bélanger *et al.* 2004). An important factor here is whether the varieties are similar in growth rhythm or not. If the varieties are similar in development, they are more likely to give similar digestibility at a certain date.

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Superior yield and nutritive value of timothy grown under cool temperatures

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Introduction

Nutritive value of cool-season grasses is known to be affected by air temperature. In timothy (*Phleum pratense* L.), dry matter (DM) digestibility declines with maturity and this rate of decline is influenced by climatic factors, especially temperature (Thorvaldsson 1992, Bosnesmo *et al.* 2005). Forage DM digestibility depends on the cell wall content and digestibility. This cell wall digestibility is usually less in forage grown at high temperature and this is attributed to an increase in lignin concentration (Wilson *et al.* 1991). To our knowledge, there are no reports on the effect of air temperature on the cell wall content and digestibility of timothy, and its lignin concentration.

Water soluble carbohydrates (WSC) are the main source of fermentable substrates during ensiling. The WSC concentration of grass species is usually higher in plants grown under cool than under warm temperatures (Deinum *et al.* 1968); at temperatures below the optimum for growth, carbohydrates accumulate because the photosynthetic rate is usually less sensitive to low temperatures than is growth (Buxton & O'Kiely 2003). Contrary to the expectation of greater WSC concentration at higher latitudes, Tremblay *et al.* (2005) observed lower concentration of WSC in timothy grown in a field at a northern than at a southern location in eastern Canada.

Air temperature also affects timothy growth; optimum air temperatures (day/night) for timothy growth and DM yield are about 21/15°C (Smith 1972). Furthermore, nutritive value is usually negatively correlated to DM yield (Bélanger *et al.* 2001). It is therefore imperative to consider both nutritive value and DM yield in studies on the effect of air temperature during growth, particularly in the context of climate change.

In this study, we assessed the effect of growth temperature on DM yield and on the concentration of WSC, neutral detergent fibre (NDF; a measure of cell wall content that includes hemicellulose, cellulose, and lignin), acid detergent fibre (ADF; a measure including cellulose and lignin), and acid detergent lignin (ADL), and on the DM and NDF digestibility of timothy. Growth temperatures were chosen to represent existing conditions in contrasted areas of eastern Canada, and predicted conditions over the next 50 years.

Material and Methods

Timothy was sown in 90 pots of 15 cm in diameter and grown in three growth chambers adjusted at 22 °C during the day and 17 °C during the night (22/17 °C) with a photoperiod of 15 h. After five weeks of growth, timothy plants were cut and grown at the same temperatures for one more week. The temperature regimes of the three growth chambers were then adjusted at either 17/5 °C, 22/10 °C, or 28/15 °C (day/night); the photoperiod remained at 15 h. Plants were grown under these three day/night temperatures and harvested three weeks later. The same experiment was repeated a second time using the same three growth chambers.

Forage DM yield was measured on 8 pots per growth chamber, for a total of 16 experimental units per treatment. Forage samples were then analyzed for ADF, NDF, ADL, and WSC concentrations, and for *in vitro* true digestibility (IVTD) of DM and NDF digestibility (NDFD). The ADF, NDF, and ADL determinations of forage samples were done using the Ankom Fiber Analyzer (Ankom Technology, Fairport, NY). The IVTD was measured using a 48-h rumen fluid digestion followed by a NDF determination of the post-digestion residues (Goering and Van Soest 1970) with the Ankom filter bag system and a rumen fermenter (Ankom Technology, Fairport, NY) according to Wilman and Adesogan (2000). The NDFD was calculated from NDF values as follows, NDFD (g kg^{-1} NDF) = 1 - (post-digestion NDF dry weight/pre-digestion NDF dry weight) × 1000. Soluble sugars were extracted with water and determined by HPLC (Bertrand *et al.* 2003). Stages of development at harvest were characterized (Simon & Park 1983).

Results and Discussion

Forage DM yield, IVTD, and NDFD were highest at low temperatures (Figure 1). With increasing day/night temperature from 17/5°C to 28/15°C, timothy DM yield decreased from 7.9 to 4.7 g pot^{-1}, IVTD decreased by 51 g kg^{-1} DM, and NDFD decreased by 96 g kg^{-1} NDF. The NDF concentration did not change with temperature treatments but the ADF concentration was lower at 28/15°C than at the other temperatures. Concentration of ADL was significantly lower in timothy grown at 22/10 °C (39.2 g kg^{-1} DM) than at 17/5°C (42.4 g kg^{-1} DM) or 28/15°C (43.0 g kg^{-1} DM). The WSC concentration was higher at 28/15°C (93 g kg^{-1} DM) than at 17/5°C (72 g kg^{-1} DM) and 22/10°C (53 g kg^{-1} DM). Stages of development at harvest were preanthesis (stage 60) for timothy grown at 17/5 °C and 22/10°C, and maximum anthesis (stage 64) for that grown at 28/15°C.

Our results confirm that DM digestibility of timothy is higher when it is grown under cool temperatures. This higher DM digestibility of timothy was not due to a decrease in cell wall and lignin concentration but was caused by an increase in cell wall digestibility, in part associated to a delay in reaching a given stage of development under cooler temperatures. The WSC concentration decreased by 26% with increasing temperature from 17/5 to 22/10°C, confirming that the WSC concentration of timothy is higher when it is grown under cool temperatures typical of northern latitudes (Deinum *et al.* 1968) The highest WSC concentration, observed in timothy grown at 28/15°C, was probably caused by a temperature stress reducing plant growth. Our results also suggest that the optimal temperature for timothy growth is less than that previously reported (21/15°C) by Smith (1972).

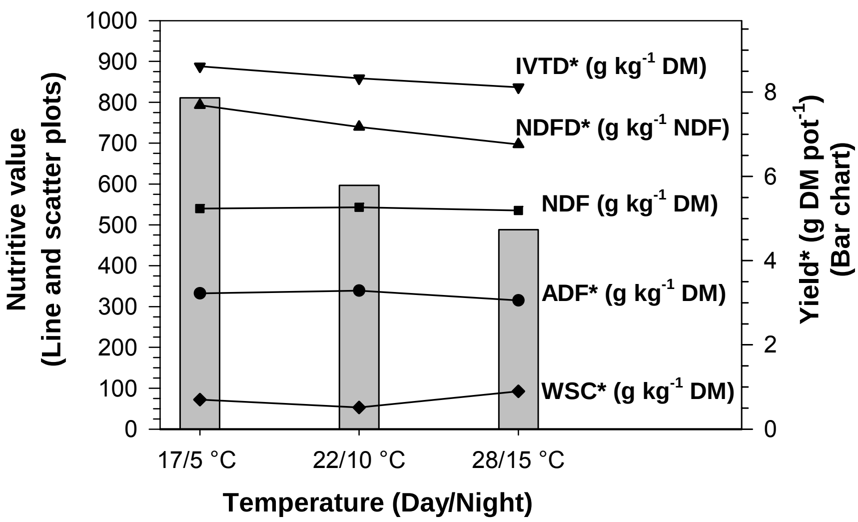

Figure 1. Effect of growth temperature on nutritive value and DM yield of timothy. *Significant effect of treatments at $P < 0.05$.

Conclusion

Cool temperatures (17/5°C), representative of agricultural areas at the northern limit of farming in eastern Canada, are more favourable for the production of timothy with higher yield, digestibility, and WSC concentration than temperatures representative of more southern locations (22/10°C). The predicted increase in air temperature over the next 50 years will likely result in lower timothy yield and nutritive value in eastern Canada.

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Morphological aspects of digestibility of timothy

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Introduction

For more sustainable milk production it is important to increase the proportion of feed produced at the farm or near the farm. In the North, the best way to do this is to use more forage and less concentrate in the ration. This makes it important to harvest forage grass of optimal quality. The managerial tactics available to producers for optimizing the digestibility of a special genotype include varying the time of harvest. The optimal harvest time varies considerably between years due to varying environmental conditions, and can differ up to three weeks between different years depending on the actual weather conditions (Gustavsson & Martinsson 2001). The dynamics in digestibility and cell wall properties are correlated with dynamics in morphology and anatomy of the shoots, and morphology and anatomy are correlated with the development stages.

Zadoks *et al.* (1974) have made a very useful scale for recording the stages of development of cereals called the decimal code. The codes refer throughout to individual plants or to the main shoots of such plants. The scale is widely used and has become the most used scheme for plant development stages in cereals. Simon & Park (1981) have modified the Zadoks *et al.* (1974) scale to suit perennial forage grasses. These two scales are very useful, but some modifications and adjustments are needed for a more stringent scale for perennial forage grasses (Gustavsson, unpubl.).

In this paper we discuss to what extent anatomy and morphology of the crop are correlated with changes in digestibility and cell wall properties, and the possibilities of using plant development stages to define the changes.

Which stages of development are most important for digestibility?

The most important stages of development for digestibility are when the first (most developed) shoots are in stage 39 - "flag leaf ligule just visible" and stage 45 - "boot swollen" - in the Simon & Park scale (1981) (Gustavsson & Martinsson 2001, Gustavsson, unpublished). Stage 39 is important in practice as a warning to the farmer that the harvest is approaching. Stage 45 is important because theoretically we can expect a break point on the curve that describes the change in digestibility over time at this stage. When the tip of the inflorescence has passed into the leaf sheath of the flag leaf of the most developed shoots in a stand, the growth of new leaves has stopped on these shoots, but the stems are still growing fast (Figure 1). In the total stand the proportion of newly formed leaves is decreasing because no new leaves appear after the appearance of the flag leaf. In the stem cell division starts to decrease, but cell elongation and cell differentiation are still going on, and the proportion of secondary cell walls increases (Figure 1).

This break point was also found in field experiments. Thorvaldsson & Andersson (1986) reported variation in rates of decrease in in vitro digestible organic matter (IVDOM) concentration in the literature. A range between 0.25 and 0.69 %-units per day was reported. Gustavsson & Martinsson (2001) found a break point with a slow decrease (0.19 %-units) before and a rapid decrease (0.74 %-units) after the time when the most developed shoots reached stage 45 (Figure 2).

Gustavsson (unpubl.) has found that over several years the break point appears when the most developed shoots reach stage 45, but that the absolute level of the curve varies between years. The IVDOM concentration of 87 % was reached between 0 and 5 days after the first shoots had reached stage 45, depending on the absolute level of the digestibility curve. The absolute level of the digestibility curve is dependent on the actual environmental conditions for the year in question, for example radiation and temperature. In Gustavsson & Martinsson (2004) a warmer year (1995) and a colder year (1996) were studied. In these years the break point for digestibility appeared when the most developed shoots were in stage 45 (Figure 2), but the break points were at different levels in 1995 and in 1996. In the warmer year (1995) the IVDOM concentration of 87 % was reached at the break point, but in the colder year (1996) the break point was at a higher IVDOM concentration (90 %), and 87 % was reached when about 20 weight-% had reached the development stage, "the inflorescence visible above the base of the flag leaf". It was thus possible to wait 5 days after the break point to come down to 87 % IVDOM.

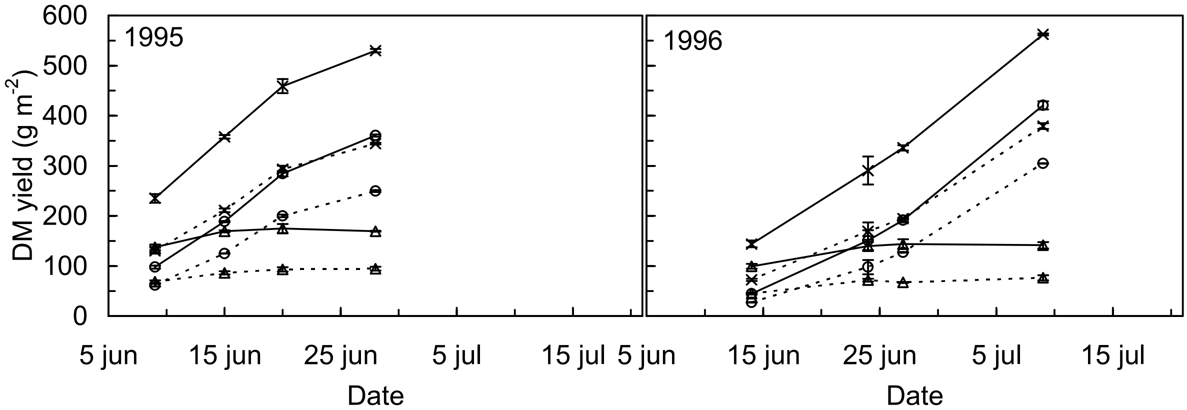

Figure 1. DM yield (g m^{-2}) (solid lines) and yield of cell walls defined as neutral detergent fibre (NDF) yield (g m^{-2}) (dotted lines) in leaves (triangles), stems (circles) and in whole plant (x) of timothy in 1995 and 1996 plotted against time (from Gustavsson & Martinsson 2004). The bars indicate the two field replications.

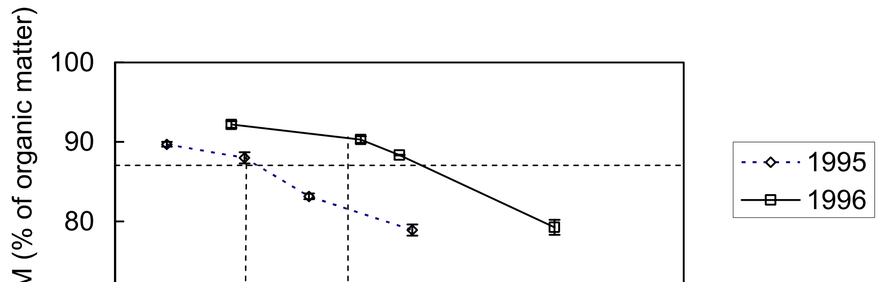

Figure 2. In vitro digestible organic matter (IVDOM) concentration. The dotted line represents the IVDOM in 1995 and the solid line in 1996. The strait horizontal line represents 87% IVDOM concentration, and the dates for when the most developed shoots reach the developmental stage 45 "boot swollen" are marked (15 June in 1995 and 23 June in 1996). The bars indicate the two field replications.

At the time when the most rapid shoots had achieved stage 45 most of the shoots had developed nodes. Only a very small proportion were still at the leave stage. Almost all shoots in spring growth were reproductive and developed nodes, internodes and heads. This was also found by Langer (1956).

Large variation

There is considerable variation, both with time and within a stand at a specific time. Firstly, in a cross pollinated perennial grass crop all shoots are not synchronized to change developmental stage at the same time. Up to six stages of development have been present at the same time (Gustavsson, unpubl.).

Secondly, we must remember that the least structural unit of all grass shoots is the phytomer, made up of a node, an internode, a leaf (consisting of a leaf laminae and a leaf sheath) and an axillary bud (meristem). At the top of the node that is situated below the internode there is a meristem where the cell division of the phytomer takes place. New internode cells are formed at the base of the internode and the older cells become higher and higher up in the internode as it grows. The oldest cells are thus in the top of the internode, and are thus the most differentiated. When the phytomer becomes older more structural compounds are built into the cell walls and the cell walls become thicker. The thickness of the cell wall is very important for the digestibility/degradability because when a cell wall becomes thicker the ratio between exposed cell wall surface that is available to microbes and cell wall volume decreases (Wilson 1993). Sclerenchyma, parenchyma and vascular tissues especially have thick cell walls compared to surface area.

Thirdly, each individual phytomer grows on its own, and the internodes of the phytomers in the lower (older) parts of the stem have more structural compounds in the cell walls than internodes higher up the stem.

Fourthly, the leaves and stems are of a different quality, and the proportion of leaves can affect the digestibility. The proportion of leaves when the first shoots reached "boot swollen" was about 50% in both years (Deinum *et al.* 1981, Gustavsson & Martinsson 2001).

One more thing we have to remember is lodging, because lodging can have very negative effects on quality if it leads to increased amounts of dead or dying plant parts. Therefore it is important to harvest the crop before or as soon as possible after lodging.

Conclusions

Despite the large variation in anatomy and morphology in a perennial grass stand it is possible to predict the dynamics in digestibility. However, we have to consider both the plant development that is important for the timing of the break point of the change in digestibility, and the environmental factors that are important, both for the plant development and for the absolute level of the digestibility curve. Harvest time predictions using calibration samples are important tools to find the absolute level of the digestibility curve.

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The effect of timothy growth stage at harvest on fermentation characteristics in round bale silage and voluntary feed intake in dairy cows

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Introduction

First cut timothy (*Phleum pratence*) silage is the fundamental high quality winter feed for high producing dairy cows on most Icelandic dairy farms and the sovereign conserving method since the early 1990's is wilted bale silage (Sveinsson 2005). It is well established that early cuts before mid heading has a substantial negative effect on timothy persistence and harvestable dry matter (DM) yield (Björnsson 2006). Also, primary timothy growth is fast and from the onset of stem elongation digestibility declines rapidly (Thorvaldsson 2006). Therefore, farmers have been advised to cut timothy no sooner or later than at mid heading to secure persistence, high DM yield and feed quality since timothy regrowth is usually poor and unreliable. Research on the effect of timothy growth stage on feed intake and animal productivity is scarce. The aim of this project was to study further the effect of timothy growth stage on silage fermentation, voluntary feed intake and milk yield in dairy cows.

Materials and methods

The silage material for this study was obtained from a first year timothy field (*var.* Adda) at Möðruvellir Research Station (65°46.239'N, 18°15.080'W and 15 m above sea level) in 1997. The field is on well drained histosol (pH 5.6) with 18-32% organic matter by weight. The vegetation cover on 6th of July was estimated to be 80-90% timothy. Remaining sward cover was mostly low yielding *Poa pratensis* and *P. annua.* Meteorological data during the first half of the growing season are described in Table 1.

Table 1. Climatic data from Möðruvellir Research Station in 1997.

	Air temperature, °C			Soil temperature, °C		Precipitation
Month	mean	max.	min.	5 cm	10 cm	mm
April	2.5	15.2	-12.5	0.3	-0.4	29
May	4.7	18.7	-6.0	3.5	2.4	32
June	7.5	16.6	-0.6	8.1	7.2	8
July	12.6	23.3	5.0	14.0	13.0	31
Mean/total	6.8	18.5	-3.5	6.5	5.6	100

Chemical fertilizer was applied in mid-May and amounted to 130 kg N, 29 kg P and 54 kg K ha^{-1}. The field, totaling 3 ha, was divided into one subfield for each growth stage. On each mowing date DM yield was determined by randomly cutting 10-15 200 x 12 cm (0.24 m^2) stripes of grass in respective subfields. The obtained samples were oven dried at 55 (+/-5) °C for at least two days before DM determination. The mowed swaths were tedded to allow rapid drying. Grass samples were taken at regular intervals, and immediately dried in a household microwave to determine the stage of wilting. The grass was raked when the desired wilting stage was reached (35% DM), baled with a round baler and wrapped in six-fold white plastic film. Four to six bales at each mowing date were weighed on a plate scale to determine average DM weight and weight per volume (Table 2).

Grass and silage samples for DM determination and feed analysis were taken in duplicates (i.e. from two bales) at baling, 1-7 days after baling, after approximately 200 days of storage and at feeding. The grass and silage samples were used to determine DM, dry matter digestibility (DMD), crude protein (CP), Ca, P, Mg, K and Na content. The silage samples were also analysed for pH, WSC (fructans, stachyose, raffinose, sucrose, glucose, fructose) and fermentation products (lactic acid, acetic acid, butyric acid, ethanol, $N\text{-}NH_3$). Details on analytical methods have been described by Sveinsson & Guðleifsson (1996, 1999).

Table 2. Timothy mowing dates, DM yield, wilting days and DM bale weight from the experimental field at Möðruvellir Research Station in 1997.

Mowing dates	Growth stage	DM yield t ha^{-1}	Wilting days	DM, kg in bale	DM, kg in m^3
7th July	I. Before heading	3.5	3	232	137
16th July	II. Mid heading	3.7	2	160	95
26th July	III. Full heading	5.8	2	196	116
Mean		4.3	2.3	196	116
S.e.d.[1]		*0.6*		*22*	*13*

[1] S.e.d. = standard error of difference

The feeding experiment took place at Möðruvellir Research Station with 12 Icelandic dairy cows weighing on average 468 (*s.d. = 45*) kg just one week before the start of the experiment. The cows were divided into 4 groups. Cows within the same group were similar in age and stage of lactation. The experimental design was a Latin square (for description see Tempelman 2004). There were three silage feed treatments (timothy silage I, II, III), and three sequential periods, three weeks each. The first week of each period was used as an adaptation for the cows to new silage. The following two weeks were used to estimate the dietary effect of silage on feed intake, milk yield and solids. All cows tested all diets. A pre-study indicated that timothy silage III would result in inadequate low feed intake which could end with health hazards for the cows if fed solely. Therefore all cows were fed a base diet, 3 kg DM of barn dried hay (consisting mostly of *P. pratensis*). Levels of concentrates were determined before the start of the experiment for each cow based on their age and lactation stage. Concentrate levels for all cows were then lowered every progressing week by 250 g. The cows were individually fed and all diets and leftovers were weighed 4 days every week. Timothy silage (I, II or III) was fed *ad libitum* and effort was made to see that silage leftovers exceeded 15% of what was offered the cows. Milk yield was measured two days every week and cows were weighed once every week. More details on this experiment have been described by Bjarnadóttir & Sveinsson (1999).

All appropriate statistical analysis was made with the aid of *GENSTAT*[tm] *Release 5.3* software (Payne 1993).

Results and discussion

The progressing growth stage in timothy at first harvest has a profound effect on dry matter digestibility (DMD), nutrient content, silage fermentation, feed intake and milk yield. The results are tabulated in Tables 3, 4 and 5.

DMD at feeding declined linearly from 784 to 633 g kg^{-1} DM from the first cut (I) to the latest cut (III) 19 days later, which is a 19% decrease (Table 3). This decline in digestibility is fairly high, according to a survey made by Thorvaldsson (2006). In his survey DMD was determined at harvest rather than feeding, as here. However, the DMD decline in samples from harvest (Table 3) was within the range given in that survey.

CP content declined even more than DMD or from 169 to 117 g kg^{-1} DM which is a 31% decrase. This was within the range in a study with timothy reported by Tremblay *et al.* (2005).

Table 3. Dry matter (DM), dry matter digestibility (DMD) and nutrient composition in timothy silages I, II and III and in the supplemental feed in the feeding experiment.

	DM			g kg^{-1} DM				
	%	DMD	CP	Ca	P	Mg	K	Na
At harvest								
silage I	37	775	165	3.2	3.1	2.3	31.8	0.3
silage II	34	726	129	2.8	2.7	2.1	25.7	0.2
silage III	39	676	94	2.6	2.2	1.7	23.3	0.2
At feeding								
silage I	36	784	169	3.4	3.6	2.4	34.6	0.3
silage II	37	715	136	3.0	3.0	2.1	31.4	0.3
silage III	36	633	117	3.1	2.4	2.0	28.1	0.4
Mean	36	718	145	3.2	3.1	2.2	31.9	0.3
S.e.d.[1]	*2.4*	*10*	*4*	*0.02*	*0.01*	*0.02*	*0.15*	*0.01*
Supplement feed								
hay	83	743	162	2.7	3.5	1.7	21.1	0.3
standard dev.	*1.3*	*15*	*5*	*0.22*	*0.13*	*0.11*	*3.0*	*0.06*
concentrate	91	900	209	19.1	14.8	3.7	8.7	9.2
standard dev.	*0.2*	*-*	*7*	*1.45*	*0.24*	*0.27*	*0.80*	*0.69*

[1] S.e.d. = standard error of difference

Table 4. Water soluble carbohydrates (WSC) and fermentation products in fully fermented timothy round bale silage cut before (I), at (II) or after (III) heading.

	Timothy silage			[1]F-		Standar error
	I	II	III	probability	Mean	of difference
DM, %	35.7	35.2	37.0	0.525	35.9	1.57
pH	5.5	4.6	4.6	***	4.9	0.10
WSC, g kg DM^{-1}						
fructans	68.0	54.0	39.8	***	53.9	3.09
stachyose	7.7	5.0	3.7	***	5.5	0.50
raffinose	5.5	1.7	0.4	***	2.5	0.40
sucrose	10.9	21.5	28.2	*	20.2	4.77
glucose	10.9	6.7	10.2	*	9.3	1.26
fructose	10.8	6.7	8.5	0.068	8.6	1.54
Total WSC	114.8	95.5	90.7	*	100.0	8.04
Fermentation products						
lactic acid, g kg^{-1} DM	26.1	51.7	47.7	***	41.8	4.40
acetic acid, g kg^{-1} DM	6.4	14.9	11.2	**	10.8	1.64
butyric acid, g kg^{-1} DM	0.0	0.3	1.8	0.162	0.7	0.90
ethanol, g kg^{-1} DM	17.6	7.5	11.5	*	12.2	3.27
NH_3-N, %	5.7	9.8	7.1	**	7.5	1.40
Total, g kg^{-1} DM	50.1	74.0	70.4	*	64.8	6.83

[1] Significance levels; *= F<0.05, ** =F<0.01, *** =F<0.001.

Timothy silage harvested before heading (I) had a higher pH, total WSC residues and ethanol content than silage harvested at mid heading or after heading (Table 4). Lactic acid, acetic acid and NH_3-N content, on the other hand, were lower in timothy silage I than in timothy silage II and III. There were only small significant differences in fermentation characteristics between timothy silage II and III. Nitrogen fertilizers applied in spring result in lower fermentation activity in early cut timothy silage but not in late cut timothy (Tremblay *et al.* 2005). This is because high nitrate and total N levels in juvenile plants cause an increase in buffering capacity which inhibits microbial fermentation compared to more mature ensiled plants with lower nitrate levels. Therefore, lactic acid fermentation is restricted in early cut silage, resulting in higher pH values and WSC residues than in late cut silage.

Forage grasses in Iceland, including timothy, have a high WSC content at harvest. The measured range in grasses at harvest in Icelandic studies is 135-295 g WSC kg^{-1} DM, depending on season, species, N fertilizer level and growth stage. WSC residues in fully fermented round bale silage is high compared to other ensiling methods. Apparent WSC disappearance during ensiling in Icelandic round bale silages is mostly at the cost of glucose and sucrose. Fructans and fructose are reduced but to a lesser extent. In a study with 6 types of round bale silages the average WSC disappearance was 109 g kg^{-1} DM and was not related to the DM content of the silage. This was on average 44% of the total WSC in the herbage at harvest (Sveinsson *et al.* 2001). It was not possible in this study to determine apparent WSC disappearance since sampling time at the start of the ensiling was not the same for all three harvest dates.

Voluntary DM feed intake, like DMD, declined linearly but the decline was much greater. Voluntary DM intake of silage I was 2.6 times greater than of silage III (Table 5). This means that with every one day delay in harvest the silage intake was reduced by 0.384 kg DM. Short term effects on milk yield and milk solids was less profound but was significantly lower when cows were fed on silages II and III compared to silage I (Table 5). The decline in milk solids yield was 14% when cows were fed silage III compared to silage I. This relatively modest decline is because cows in good condition, like those in this experiment, are capable of resisting changes in milk yield when fed an energy varied diet as here by using body reserves to balance their needs. Also, half of the cows were 1st calf heifers and still growing, which may have reduced the dietary effect on milk yield.

Table 5. The effect of timothy growth stage on daily feed intake and milk yield in Icelandic dairy cows.

	Timothy silage			[1]F-probability	Mean	Standar error of difference
	I	II	III			
Daily intake, kg DM						
timothy silage	11.8	7.5	4.5	***	7.9	0.40
hay	2.8	3.0	3.2	***	3.0	0.04
concentrate	3.3	3.3	3.3	0.968	3.3	0.03
Total intake	17.9	13.8	11.0	***	14.2	0.40
Daily intake, % of body weight						
timothy silage	2.52	1.60	0.98	***	1.70	0.087
hay	0.60	0.64	0.70	***	0.65	0.013
concentrate	0.70	0.70	0.71	0.839	0.71	0.014
Total	3.80	2.93	2.37	***	3.03	0.094
Milk yield and solids						
[2]ECM, kg day^{-1}	18.5	17.0	16.2	***	17.2	0.26
fat, g day^{-1}	748	679	651	***	692.6	15.1
protein, g day^{-1}	621	564	533	***	572.6	13.9

[1] Significance levels; *= F<0.05, ** =F<0.01, *** =F<0.001.
[2] ECM = energy corrected milk

Another important factor in voluntary intake, but not presented here, is the lactation stage. Cows in their early stages of lactation and higher yielding eat profoundly more than low yielding cows. In this study voluntary DM intake by cows yielding 26 kg ECM day^{-1} was 1.31, 1.41 or 1.52 times greater than by cows yielding 10 kg ECM day^{-1} when fed silage I, II or III, respectively.

A Swedish study with timothy bunker silage cut at three maturity stages (though within only a 10 day range) and offered lambs and dairy cows showed a significant decline in total feed intake with increased timothy maturity (Bernes *et al.* 2004). The effect was more profound in lambs than cows. Live weight gain (LWG, g day^{-1}) in lambs fed "late" cut timothy silage was 0.5 times the LWG in lambs fed "early" cut timothy silage. This Swedish study and the one presented here show the importance of harvest dates (i.e. growth stage) for the feeding value in timothy. Within just a relatively short time range, voluntary feed intake moves from being exceptionally high to being exceptionally low. Daily intake of an early cut timothy based diet as a per cent of body weight is remarkably high or 3.80% in this study (Table 5). Other Icelandic studies show that early cut timothy-based polymorphous diets for dairy cows is sovereign over other grasses when it comes to feed intake per body weight (Sveinsson *et al.* 2001).

The overall conclusion of this study is that primary growth of timothy has to be cut for silage well before mid heading to obtain maximum feed quality for dairy cows. Later cutting dates for primary growth in timothy are not acceptable for high lactating cows and fast growing ruminants.

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Description and evaluation of a decision support tool predicting quality and yields in swards with timothy

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Introduction

Bonesmo has previously developed a site-specific concept or model for decision support of cutting time for farmers and the extension services (Gustavsson *et al*. 2003, Bonesmo & Bakken 2005). The present version of the decision support tool calculates daily values of DM yield, phenological development and yield NDF content (Figure 1). The inputs are daily measurements of global radiation, temperature, precipitation and potential evapotranspiration from a network of automatic weather stations. The tool is based on simple but flexible algorithms with few and adjustable parameters, and the aim and idea are that it should function for single species as well as for mixed swards under very different soil and environmental conditions.

In this presentation we have given an outline of how the tool is constructed and have further demonstrated the precision of its predictions.

Model description

The model is written and run in Microsoft Excel, and the adjustable parameters are optimized by the Excel Solver according to data sampled from the site-specific sward previous to harvest. The present recommendation is to do the first sampling at early stem elongation of timothy (or the dominant grass species) and a second one about one week later.

At the sampling occasions, the sward height (Mould 1992), grass phenological stage (Mean stage by count, MSC) (Moore *et al*. 1991) and preferably yield NDF content are recorded/analysed. A simple regression equation transfers the height recordings to estimates for standing DM yield.

The parameters marked with red colour (or dark grey in B&W) in Figure 1 are optimized, whereas those marked with light blue colour (or light grey in B&W) are set as constant in the present version of the tool.

Bakken *et al*. (2006) and Bonesmo (2004) give explanations of symbols, variables and parameters in the phenological function.

The equation for daily yield increment (*dW*), is developed from Bonesmo (2000) and is in principle the potential growth rate (the term containing *Cm*, the maximum growth rate) multiplied with a dimensionless growth index (*GI* = Radiation index × Temperature index × Water index × Aging index). All indeces are scaled from 0 to 1. R_m is the initial maximum growth rate, *K* is a radiation extinction coefficient and L_0 is the initial leaf area index.

The daily rate of change of the NDF concentration (*dNDF*) is calculated from the phenological function (*f(P)* visualized in Figure 2) multiplied with the parameter P_u, which expresses the maximum deposition of NDF (cell walls). The parameter P_m expresses the MSC at which the function attains its maximum, and P_k is the slope of the function (Figure 2). P_0 is the MSC at which development starts.

Model performance and suggestions for improvements

The examples of model performance presented in Table 1 reveal considerable, and perhaps not, acceptable discrepancies between predicted and harvested yields. If actual pre-harvest standing biomass instead of canopy height recordings were used as input data, the predictions improved considerably (data not shown). Further work is consequently needed to (if possible) find equations that describe the relationship between sward height and biomass more accurately.

Table 1. The differences between predicted and recorded yield (kg DM ha^{-1}) and yield NDF content (proportion, w/w, of DM) in mixed swards with timothy, meadow fescue and red clover at two sites.

	Date of calibration sampling		Numeric difference between predicted and harvested yield and NDF content					
Site and year	1st	2nd	date	yield	NDF	date	yield	NDF
Kvithamar 2004	18 May	28 May	4 June	260	-0.03	15 June	-4120	-0.02
Kvithamar 2005	19 May	27 May	4 June	-1119	0.05	14 June	-990	0.10
Særheim 2005	20 May	23 May	30 May	-950	-	6 June	-2120	-

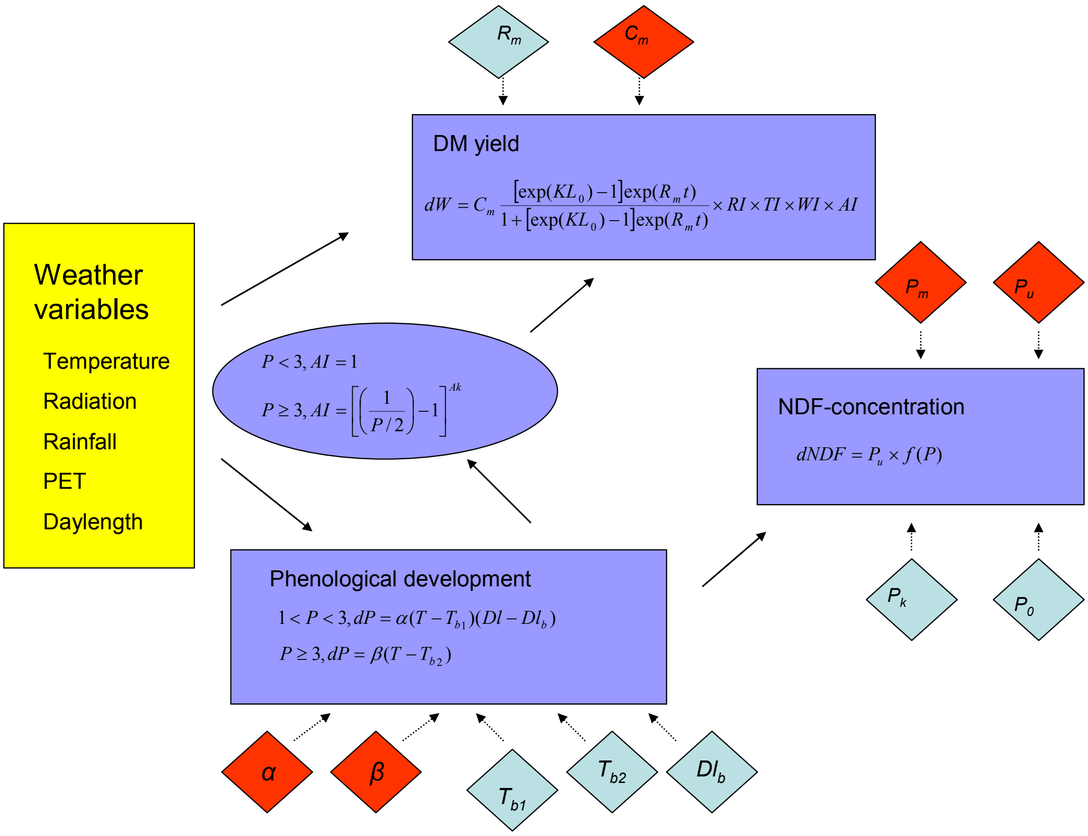

Figure 1. An outline of input variables, rate functions and parameters in a decision support tool for predictions of yield and yield quality. Parameters marked with red colour are optimized for site-specific swards and those marked with light blue colour are set as constant.

The predictions for phenological stage of development at harvest were in rather good agreement with observations in the swards (Figure 3). The phenological function is more comprehensively discussed by Bakken *et al.* (2006). To improve the predictions of NDF content (Table 1), and possibly partition the NDF fraction into a digestible and a non-digestible one, both the relationship between development and cell wall deposition and directly between weather variables and assimilate partitioning must be assessed further.

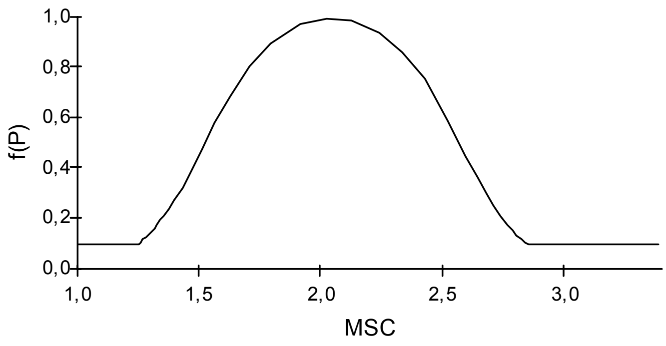

Figure 2. Outline of the function weighting the calculation of deposition of NDF in the grass sward according to stage of development. Its minimum, maximum and slope might vary.

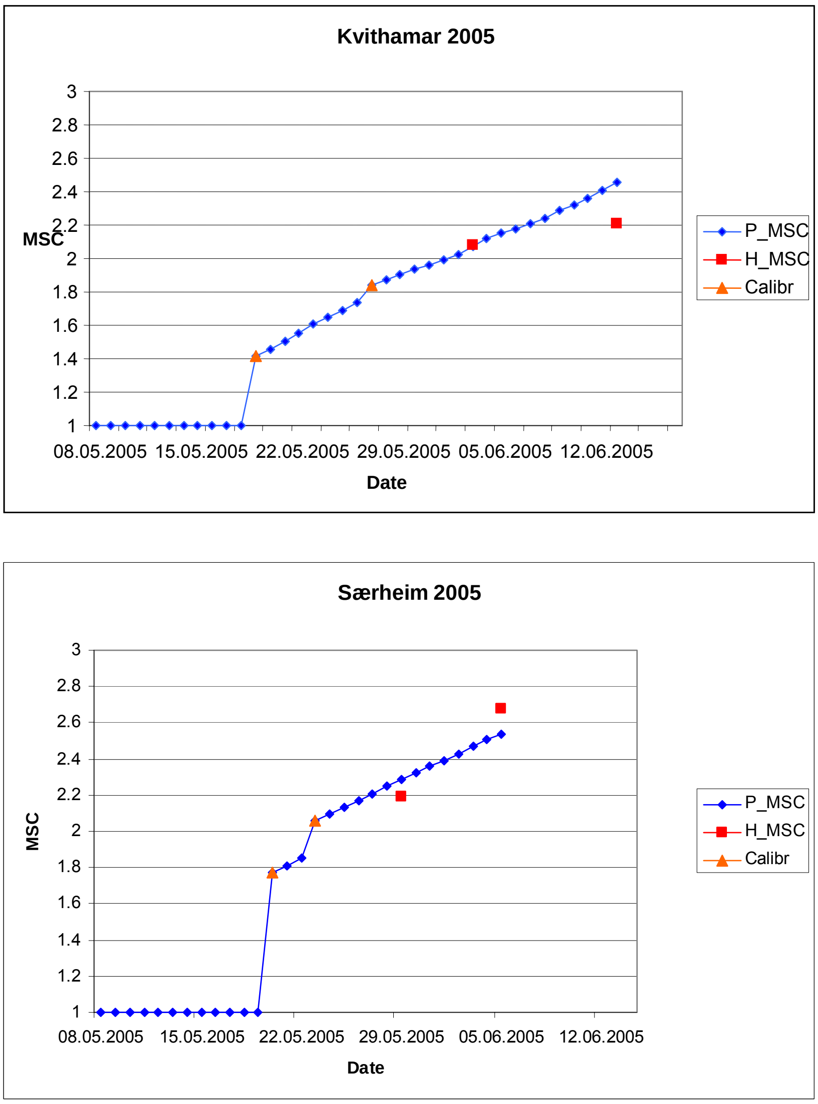

Figure 3. Mean stage by count of timothy as predicted by a decision support tool (P_MSC) and as determined at sampling occasions for calibration (Calibr) and at later harvests (H_MSC) at the sites Kvithamar and Særheim.

It is also our ambition that functions for prediction of crude protein and energy content will be included in the tool and that 5- or 10-day weather forecasts will be linked up to draw the prediction beyond real time.

The present version also works for regrowths, and results from test runs not presented here indicate that yields are predicted quite well when some minor changes are made. It is possible that quality in regrowths, especially those not dominated by timothy, should rather be linked to a heat sum function independent of progress in phenological development, than to MSC. The last one will not make much sense for descriptions of aging and quality changes in swards with mainly vegetative tillers.

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Posters

Sláttuvísa (4)	*Mowing Song (4)*
Arfi lýtur orfi,	*All the flowers have fallen,*
allar rósir falla,	*fairest grasses perish:*
stutta lífið styttir	*life is brief, aborted*
sterkur karl í verki,	*by the ripper's stripping.*
heft er hönd á skafti,	*Haft is humming softly,*
hrífan létt mér ettir,	*hefted firmly, deftly;*
glymur ljárinn, gaman!	*iron edge is tireless;*
grundin þýtur undir.	*under him, earth thunders.*

Jónas Hallgrímsson (1807-1845) — *translated by Dick Ringler*

“Jónas Hallgrímsson is the best loved and most admired poet of modern Iceland: ástmögur þjóðarinnar ("the darling of the nation"). His work transformed the literary sensibility of his countrymen, reshaped the language of their poetry and prose, opened their eyes to the beauty of their land and its natural features, and accelerated their determination to achieve political independence…”

Dick Ringler
http://www.library.wisc.edu/etext/Jonas/

Effect of quality assessment on cultivar performance in timothy variety testing in Finland

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Introduction

Official variety trials are conducted in Finland by the Plant Production Research unit of MTT Agrifood Research Finland. Owners of the variety rights enter varieties into the trials and cover the expenses involved. Forage grass varieties undergo official trials for a minimum of three years or until the variety is withdrawn from testing or is entered in the National List of Cultivars of the Ministry of Agriculture and Forestry. If the variety is accepted on the National Lists of Varieties it will usually continue in trials for a further 2-3 years to provide growers with additional information. Decisions on the inclusion of varieties in the National List of Varieties are made by the Plant Variety Board of the Ministry of Agriculture and Forestry. The principal characteristics used to assess new timothy varieties for inclusion in the National List of Cultivars are dry matter yield, yield at first cut, yield of regrowth and extent of winter damage.

Grasses are predominantly used for silage in Finland. Two or three cuts are taken during the growing season. Successful timing in harvesting the primary growth is critical as grasses develop very rapidly at a day length of >18 hours and a daily mean temperature close to 20°C. The primary growth has to be harvested within a short period to secure a yield of high digestibility. According to Huhtanen (2001), digestibility (D-value) of the silage falls away at 0.5% unit per day during primary growth. For second and third harvests, change in digestibility is much slower than for the first cut. In timothy variety trials all cultivars are harvested at the same date to reduce labour. Although differences in earliness among timothy varieties are relatively small under Finnish growing conditions, there are differences that are likely to lead to quality differences among yields harvested on the same date.

Assessment of quality parameters in forage grass variety trials has been very limited until now because of the high cost of traditional digestibility assessment and fiber fractioning methods. Quality assessment of forage would, however, be particularly useful in Finland as most grass is harvested for silage in two or three cuts. In countries where grasses are grazed during most of the year, quality assessment may not be as useful as quality can be presumed to remain adequately high when the grass is consumed at the vegetative stage.

Forage quality assessment using near infrared spectroscopy (NIRS) has been applied routinely in forage breeding for a long time. It has been used in variety testing in Norway for many years. In Norway samples are taken from all cuts in the first year stands and organic matter digestibility (% DM), protein (% DM), neutral detergent fibre (% DM) and carbohydrate content (% DM) are analysed and also values of milk units (units/kg DM) are recorded (Moltenberg & Engerer 2003).

The aim of this paper is to present preliminary results of quality analyses of timothy varieties tested in Finland and to assess how taking these quality characteristics more into account would affect performance evaluation of cultivars differing in key characteristics.

Material and methods

Yield samples for this study were taken from timothy variety trials in 2000-2004. In 2000, samples were taken only for the reference varieties, but in 2001-2004 samples were taken of all varieties included in the variety testing programme. Experiments were conducted at 10 trial sites in various parts of Finland. Samples were taken from first and second year stands. At least two cuts were taken during each season. In seven experiments of a total of 44 including the variety Tammisto II three cuts were taken in each season. All cultivars in the trial were harvested at the same time. The first cut was taken when 20-30% of ears had emerged from leaf sheaths in the reference variety.

Samples were dried at 100°C for one hour and subsequently at 60°C until completely dry (usually overnight). NIRS analyses were carried out at MTT Agrifood Research Finland laboratory. The NIRS equipment (Braen Luebbe; Infra Analyser 500) was calibrated for samples taken using the same procedure as used in the variety test trials. Quality parameters analyzed by NIRS included digestibility of organic matter in dry matter (D-value), acid detergent fibre (ADF), neutral detergent fibre (NDF), acid detergent lignin and nitrogen content, which was converted to raw protein by multiplying the value by 6.25. Results of D-value, NDF and protein content are presented in this paper.

Results for four various types of variety are presented in this paper. Tammisto II (Boreal Plant Breeding Ltd.) was the reference variety and is commonly sown. Grindstad (Tollef Grindstad), from southern Norway, represents a more southern type of timothy than Tammisto II. Iki (Boreal Plant Breeding Ltd.) is a northern type with less regrowth than the other varieties. Linus (SW Svalof Weibull) represents a slightly later cultivar than Tammisto II. Based on the date of heading, Grindstad is earlier than Tammisto II. Iki is also slightly earlier than Tammisto II.

The set of cutivars varied among experiments. Therefore, the number of trials (one year at one trial site, including results of all cuts) from which quality assessment data are available varied among varieties. In this data set, the reference variety Tammisto II had 44 results, Grindstad 28, Iki 17 and Linus 17. The data were analysed using linear mixed models and the REML estimation method, which take account of all available data in the same analysis. Variety was selected as a fixed effect in the model, and effects of site, year and trial were regarded as normally distributed random effects (Öfversten, J. and Nikander, H. 1996). Analyses were performed using the SAS/MIXED procedure. In the results all cultivars can be compared directly with each other. In Tables 1 and 2, significance levels show how likely a difference between the reference variety (Tammisto II) and the test cultivar was due to chance. The statistical significance levels are: o= significant at 10 % level, *= significant at 5 % level **=significant at 1 % level, ***= significant at 0.1 % level.

A summary of the results during the last eight years is provided. The latest publication covering 1998-2005 was reported by Kangas *et al.* 2006. The quality assessment results used in this preliminary study were not included in that data set.

Results

Characteristics of the four example varieties used in this study are given in Table 1 and are presented according to the traditional variety testing scheme. In heading Grindstad and Iki were slighly earlier and Linus later than Tammisto II (Table 1). The higher DM content of the first cut of Grinstadt illustrate earliness as well as lower DM content compared with Tammisto II. The high yield of the second cut and high percentage of regrowth yield of Grindstadt indicate that it is a southern type. Iki and Linus have reduced regowth capacity, indicating early preparation for winter typical of northern types.

In Table 2, D-value, NDF and raw protein content of cultivars for the first and second cuts are given. At the first cut the D-value of Grindstad was significantly lower that that of Tammisto II and the D-value of Linus was significantly higher that that of Tammisto II. At the second cut the D-value of Grindstad was significantly lower than that of Tammisto II. The D-values for Linus and Iki were significantly higher that for Tammisto II at the second cut.

Table 1. Characteristics of timothy varieties based on data from traditional variety descriptions. The data set includes all results for the variety in the variety data bank 2000-2004. Statistically significant differences between the means of a test variety and the reference variety Tammisto II are indicated with asterisks.

Variety	Results	Winter damage %	Days to heading from 1.5.	DM 1st cut %	DMY 1st cut kg ha^{-1}	DMY regrowth kg ha^{-1}	DMY total kg ha^{-1}	Regrowth of total DMY %
Tammisto II	73	4.9	46.0	21.6	5289	5072	10361	49
Grindstad	54	5.5	44.4***	23.1***	5258	5866***	11124***	53
Iki	64	4.5	45.6***	21.7	5284	4684***	9968***	47
Linus	33	4.1	46.7***	21.0***	5165	4614***	9779***	47

For protein content at the second cut it is likely that the lower value for Grindstad resulted from high yield and the higher protein content for Linus and Iki resulted from their low yield at the second cut. The higher lignin content for the second cut of Grindstad (43.9 g kg^{-1} DM), compared with the value for Tammisto II (41.7 g kg^{-1} DM) may explain the lower D-value for Grindstad although NDF content was similar for Tammisto II and Grindstad. The difference in lignin content was statistically significant. Lignin content of Linus at the second cut was 40.1 g kg^{-1} DM, which was significantly lower than for Tammisto II.

Table 2. D-value, NDF and protein content of timothy varieties at the first and second cut in the test study. The data set was compiled from data from 2000-2004. Statistically significant differences between the means of a test variety and the reference variety Tammisto II are indicated with asterisks.

		Quality parameters for the 1st cut			Quality parameters for the 2nd cut		
Variety	Results	D-value %	NDF g kg^{-1}	protein g kg^{-1}	D-value %	NDF g kg^{-1}	protein g kg^{-1}
Tammisto II	44	68.4	649	116	68.1	638	101
Grindstad	22	67.7**	639*	112*	66.6***	637	91**
Iki	17	68.7	648	115	69.8***	629	110
Linus	17	69.4***	634***	120*	70.3***	629	112***

Table 3 represents a summary of results for yield at first and second cuts when total yield is given as dry matter yield (DMY) and as digestible yield (DIY), which is obtained using the D-value to calculate DIY from dry matter yield. The earlier Grinstad performed better in the traditional DMY in comparison with Tammisto II (106***) than in the DIY comparison (104***). However, the DIY of Grindstad remained significantly higher that that of Tammisto II. Iki and Linus benefited from the use of DIY. The relative figures for DMY and DIY of Tammisto II improved from 98 to 99 and from 95** to 97^{o} for Iki and Linus, respectively.

Table 3. Dry matter yield (DMY) and digestible yield (DIY) of timothy varieties for first and second cut and for total yield. Digestible yield was calculated from DMY and the D-value. The data set was compiled data from 2000-2004 including only trials where the quality was analysed. Statistically significant differences between the means of a test variety and the reference variety Tammisto II are indicated with asterisks.

		Yield of 1st cut		Yield of 2nd cut		Total yield		Total	Total
Variety	Re-sults	DMY kg ha^{-1}	DIY kg ha^{-1}	DMY kg ha^{-1}	DIY kg ha^{-1}	DMY kg ha^{-1}	DIY kg ha^{-1}	DMY rel	DIY rel
Tammisto II	44	5307	3642	5080	3447	10701	7310	100	100
Grindstad	22	5181	3510^{o}	5792***	3845***	11361	7626	106***	104***
Iki	17	5477	3763	4656**	3241*	10469	7248	98	99
Linus	17	5202	3606	4632**	3237*	10146	7068	95**	97^{o}

Discussion

Significant differences in quality parameters among varieties were recorded for yields of both the first and second cuts (Table 2). Differences in D-values reflected the differences in earliness of varieties and differences in protein content reflected differences in the yield of a particular cut. When D-values were taken into account in calculating digestible yield from dry matter yield the performance of Linus was improved. Iki also performed better when the D-value was taken into account. The D-value for Iki was higher, particularly for the regrowth, than that of Tammisto II. Performance of the early variety Grinstad was not as good when the D-value was taken into account as when only dry matter yield was considered. Quality assessment of yield in variety trials would provide valuable evaluation information. In addition, it would provide useful data to study the effects of other factors (climate, cutting regime) on quality of timothy.

Quality assessment in cultivar trials would motivate breeders to enhance their efforts in quality improvement. A decision has been made in Finland to include quality assessment in the forage cultivar testing programme. The sampling procedure has been modified so that drying will be done at a constant 60°C. The quality characteristics to be recorded and analysed are being discussed.

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Dehardening in timothy and perennial ryegrass during winter and spring

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Introduction

The ability of perennial grasses to maintain frost hardiness throughout the winter and to resist dehardening during periods of mild weather is crucial for winter survival in the northern region. Former studies by Eagles (1994) and Larsen (1994) have shown that varieties of timothy adapted to northern conditions do not deharden as readily as southerly varieties. The reason for this is unknown, but there seems to be a tendency that northern ecotypes of timothy retain frost hardiness for a longer period of time than southerly ecotypes, especially at low to moderate ambient temperature conditions, until spring.

In this study we tested whether cultivars of timothy of northern origin are more resistant to dehardening than southern cultivars during periods of mild weather in winter, and if the rate of dehardening is accentuated in spring compared with winter. We also tested whether cultivars of perennial ryegrass with different degrees of winter hardiness behave differently when exposed to dehardening conditions.

Materials and methods

Two contrasting varieties of timothy (*Phleum pratense* L.), cv's Grindstad and Engmo, and two of perennial ryegrass *(Lolium perenne* L.) cv's Gunne and Riikka were established at the end of May 2005 at Holt, Tromsø (69^0 65'N). The plants were established by transplanting 14 day old seedlings from seed trays to 10 l black polythene bags filled with a fertilized peat-sand mixture, 10 seedlings per bag, and placed in the field. Dehardening treatments started in January and April when bags with plants were brought from the field. The plants were left to thaw for 3-4 days at 3^{o}C and no light to ensure that the soil was unfrozen. Thereafter the plants were transferred to a phytotron and set under different dehardening treatments of 3^o, 9^o or 15^{o}C, 12 h light. The effects of dehardening treatments on the plants were measured as frost hardiness (LT_{50}) by performing freezing tests on single tillers after 0, 2, and 6 and 9 days under the dehardening temperature conditions. Before freezing tests the plants were split into homogeneous single shoots and cut to1cm roots and 3cm from crown to top according to Larsen (1978). Bundles of 10 or 8 shoots were placed in moist sand in aluminium trays and left ca 12h at ca –1 to –2^{o}C to freeze homogeneously. The bundles, two parallels per variety and temperature, were then frozen to predetermined temperatures ranging from –29 to –2^{o}C at a freezing rate of 3^{o}C h^{-1}. After freezing, the plants were left to thaw overnight at 3^{o}C and no light. Control samples of tillers were also left unfrozen at 3^{o}C and no light during the period of freezing treatment. The tillers were then transplanted into trays filled with soil and left at 18^{o}C and 24h light for approximately 21 days when survival was evaluated. LT_{50} was calculated by using SAS procedure probit analysis.

Results and discussion

A freezing test performed in October showed that the LT_{50} of Engmo and Grindstad were similar (–16.3 and –15.7^{o}C, respectively), whereas Gunne and Riikka were considerably less frost tolerant with a LT_{50} of -7.4 and –8.8^{o}C, respectively (Höglind *et al.* 2006). The degree of hardiness in Engmo and Grindstad was lower than found by Larsen (1994) in Bodø (67^{o}18'N) at a similar time. This may reflect the unfavourable hardening conditions for the plants as the autumn in Tromsø in 2005 was characterised by relatively high temperatures and a lot of precipitation (Figure 3).

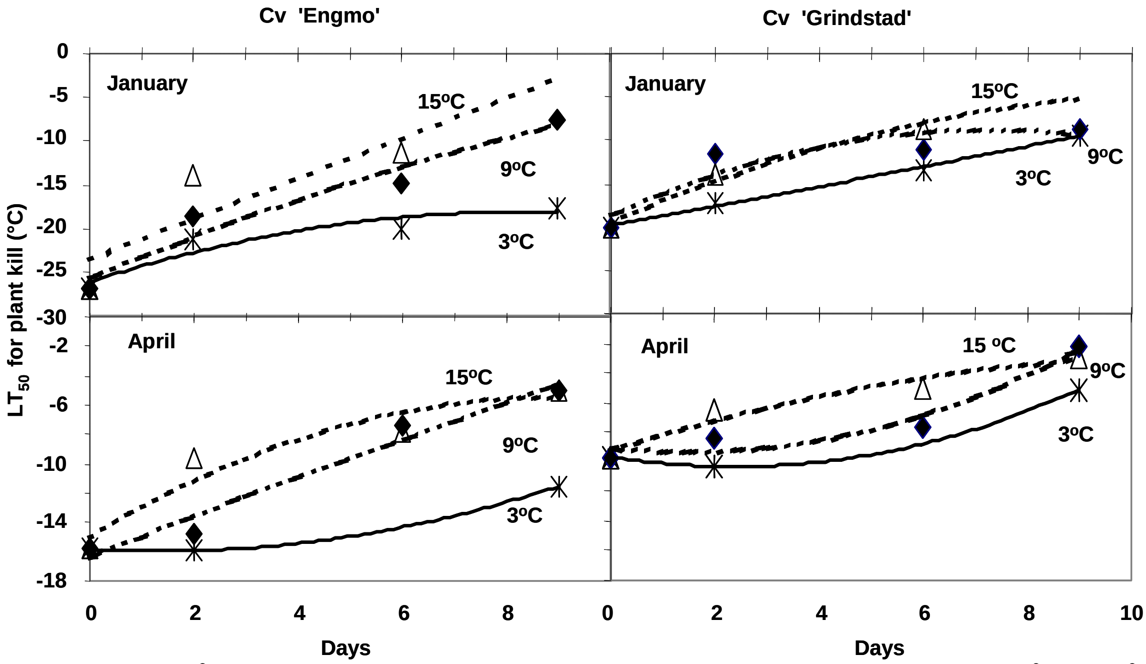

Figure 1. LT_{50} (C^o) during dehardening of timothy (*P. pratense*) cvs, 'Engmo and 'Grindstad at 3^{o}C (ж), 9 ^{o}C (♦) or 15 ^{o}C (Δ) in January and in April. Each point is the estimated LT_{50} value based on probit analyses of freezing tests, and the curves are the fitted trends to each of the dehardening conditions.

At the start of the dehardening treatments in January, Engmo timothy was considerably more winter hardy than Grindstad with a LT_{50} below -26^{o}C compared with -20^{o}C in Grindstad (Figure 1). When treated with 3^{o}C, Engmo retained most of its hardiness during 9 days of dehardening, whereas Grindstad became considerably less hardy (–9.3^{o}C). During the 9 days of dehardening at 9^{o}C the hardiness decreased to a LT_{50} of –8.7 and –7.6^{o}C in Grindstad and Engmo, respectively, and this shows that the rate of dehardening in fact was higher in Engmo (-2.16^{o}C day^{-1}) than in Grindstad (-1.25^{o}C day^{-1}). The rate of dehardening was higher at 15^{o}C, than at 9^{o}C after 6 days of dehardening, both in Engmo and Grindstad (Figure 1).

During the second round of dehardening, a similar pattern as in the first round was found. The initial LT_{50} of Engmo was –15.8^{o}C, whereas it was only –9.7^{o}C in Grindstad. The rate of dehardening was not higher than in the first round with -1.2^{o}C day^{-1} and -0.75^{o}C day^{-1} in Engmo and Grindstad, respectively at 9^{o}C dehardening. Also in this round, Engmo retained most of its hardiness at the 3^{o}C dehardening treatment. The results show that under the prevailing conditions, Engmo generally had a higher degree of hardiness than Grindstad and maintained a higher degree of hardiness at 3 ^{o}C. However, Engmo lost its frost tolerance at a higher rate than Grindstad when treated with 9^{o}C and 15 ^{o}C. Eagles (1994) found that Engmo had a lower rate of dehardening than Grindstad when treated with dehardening conditions below 10 ^{o}C and 8h photoperiod, whereas at 10 ^{o}C and above the rate of dehardening was similar. It could be that Engmo has a different threshold temperature for dehardening than Grindstad, and the length of photoperiod may also be important (Eagles 1994).

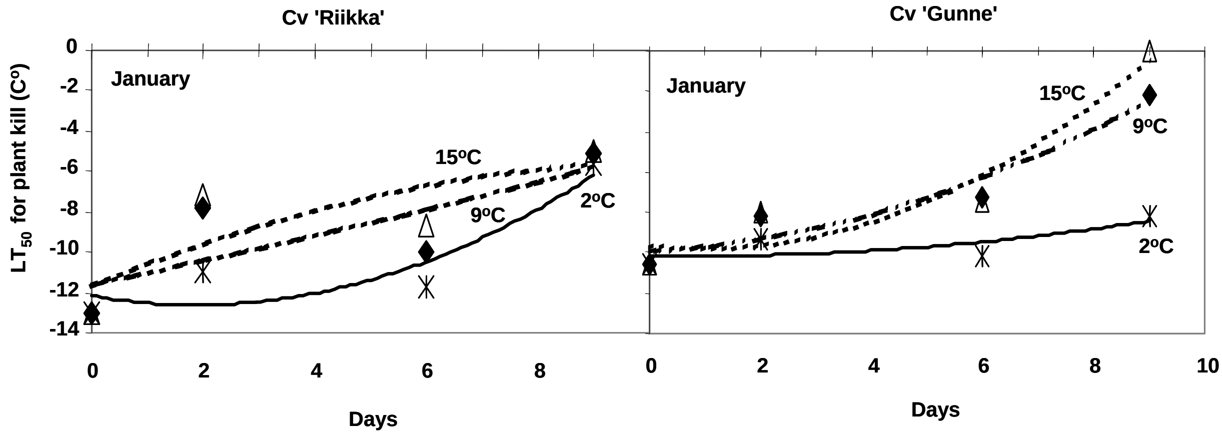

Figure 2. LT_{50} (C°) during dehardening of perennial ryegrass (*L. perenne*) cvs, 'Riikka and 'Gunne at 3°C (ж), 9 °C (♦) or 15 °C (Δ) in January. Each point is the estimated LT_{50} value based on probit analyses of freezing tests, and the curves are the fitted trends to each of the dehardening conditions.

Perennial ryegrass had a much lower initial hardiness in January than timothy with LT_{50} –10.6°C in Gunne vs. -13°C in Riikka (Figure 2). During 9 days of dehardening, the hardiness of Riikka dropped to around -5°C in all treatments, whereas Gunne lost all its frost hardiness when dehardened at 9 and 15°C, and retained a lot of hardiness at 2°C. January was characterised by mild weather and no snow, while the soil was frozen (Figure 3). This led to a build-up of ice sheets as temperatures dropped in February. Perennial ryegrass was particularly affected by these difficult winter conditions, and the plants were in very bad shape when brought in from the field in April. Therefore, no dehardening curves could be presented from April as between 10-50% died from unfrozen controls. Riikka is a more winterhardy type variety than Gunne, and the results agree with observations in the field, where Riikka was able to survive to a certain degree, while almost all Gunne plants died off.

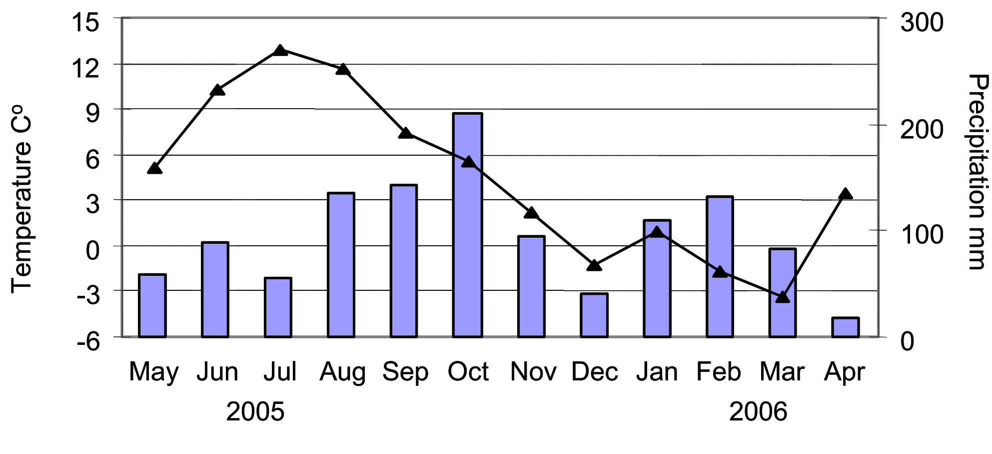

Figure 3. Mean monthly air temperature (line) and precipitation (bars) at Holt during the experimental period.

The study did not confirm the hypothesis that the more winter hardy cultivars deharden more slowly than the less frost tolerant cultivars. However, further studies need to be conducted to investigate in more detail whether there is a differing threshold temperature for dehardening between cultivars, and whether photoperiod may also be involved in the rate of dehardening.

This study is funded by the Norwegian Research Council and Bioforsk as part of the WINSUR research programme (Climate change effects on winter survival of perennial forage crops and winter wheat and on plant diseases and weed growth and control at high latitudes) 2004-2008.

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Root regeneration ability in cultivars of timothy and perennial ryegrass subjected to mild frost stress.

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Introduction

The ability of perennial grasses to regenerate roots after a frost kill may be critical for winter survival. Roots and other protected parts have a lower ability to harden compared to aerial parts, and in winter cereals it has been shown that lack of root development limited the ability of plants to re-establish after freezing (Chen *et al.* 1983). In this experiment we tested whether northern cultivars are able to regenerate roots faster than southern cultivars. We also looked for possible relationships between plant age and root regeneration ability in winter and spring.

Material and method

Two contrasting varieties of timothy (*Phleum pratense* L.) 'Engmo' and 'Grindstad' and perennial ryegrass (*Lolium perenne* L.) 'Riikka' and 'Gunne' were established at two different dates (May and July) in 2005 at Fureneset, Fjaler, West Norway (61ºN) to obtain plants at different developmental stages prior to winter. The plants were established in 10 dm^3 black polythene bags filled with a fertilized peat-sand mixture, 10 seedlings per bag, four replicates (bags) per cultivar, and placed in the field. During the growing season the plants were cut twice and fertilized according to normal farming practice. In October (reg. 1) at the end of the growing season, root biomass was determined and samples for carbohydrate analyses were taken (3 cm of crown and lower stem).

Root regrowth studies were performed in late January (reg. 2), early March (reg. 3) and late April (reg. 4). Crown segments were sampled for carbohydrate analyses. From each bag, 10 tillers were transferred to a heated greenhouse. Remaining plants received an additional treatment of moderate frost (-8 to -10ºC) for two days before transferring 10 frost treated tillers. During frost treatment bags were insulated to prevent direct root damage. Before planting roots were cut off and shoots trimmed to 5 cm length. Regrowth was registered during the following four weeks (15ºC, continous light) on the basis of changes in dry weight (dw) of roots.

Results

Root growth ability in northern vs. southern cultivars after frost treatment

In winter (reg. 2) significant differences for root growth were found between frozen and non-frozen plants and between species. In spring (reg. 4) significant differences were found between frozen and non-frozen plants and between cultivars. Analysing frozen and unfrozen plants separately, in frozen plants of Engmo timothy root dw was significantly higher than all other cultivars, whereas in unfrozen plants of Engmo timothy root dw was significantly higher than in Gunne perennial ryegrass. Engmo produced the most root dw of the studied cultivars throughout the winter and spring .

Root dw for non-frozen (control) and frozen timothy and perennial ryegrass cvs are presented in Figure 1 as mean values for two sowing times. In winter (reg. 2) both timothy cvs had higher root dw in the frost treated tillers compared to untreated and the same results were obtained for Engmo in reg. 3. In spring (reg. 4), on the contrary, root dw in Engmo after frost treatment was 91% of that of the non-frozen Engmo tillers. The corresponding result for Grindstad was 55%. In spring (reg. 4) root dw of non frozen tillers was 67% in Grindstad compared to Engmo. The ryegrass cvs produced less root dw than the timothy cvs. In spring (reg. 4), Gunne produced 59% less root biomass than Riikka for non-frozen tillers. In Gunne, frost treated tillers produced 44% less root biomass than non-treated tillers. The corresponding result for Riikka was 57%.

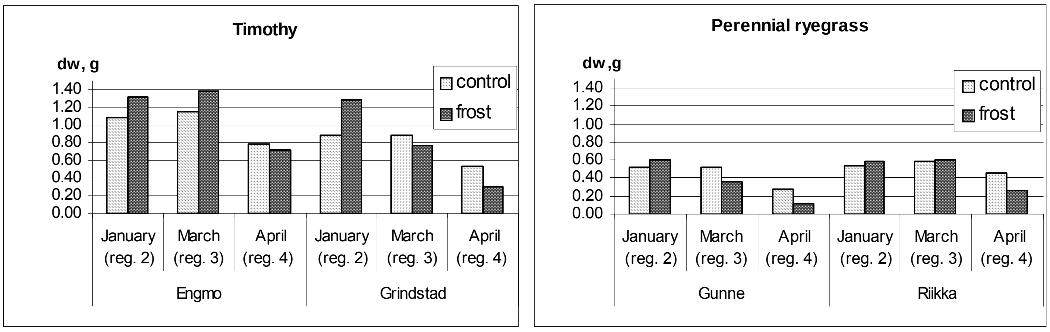

Figure 1. Root regrowth (dw) after root cutting at various times in winter and spring in timothy (Engmo, Grindstad) and perennial ryegrass cvs (Gunne, Riikka) affected by frost treatment. Means of two sowing times.

Root growth in plants with different plant ages

Significant differences were found for dw root biomass in autumn (reg. 1) for sowing time, cultivars as well as for sowing time x cultivars. Mean root dw was 12.4 g and 2.4 g as a mean for all cultivars for plants sown in May and July, respectively. Mean values were similar for timothy and perennial ryegrass cultivars for the May sowing, whereas for the July sowing timothy had 69% of the ryegrass root biomass. Greater differences were observed between the perennial ryegrass cultivars compared to the timothy cultivars.

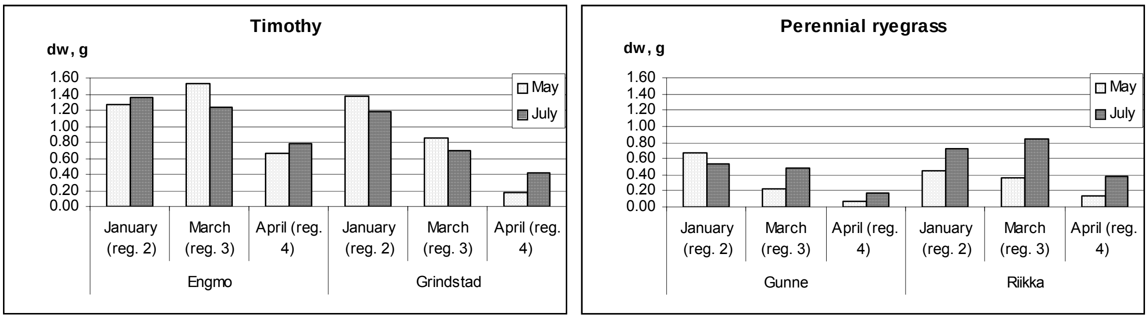

Figure 2. Root regrowth (dw) after root cutting and frost treatment at various times in winter and spring in timothy (Engmo, Grindstad) and perennial ryegrass cvs (Gunne, Riikka) affected by early (May) and late (July) sowing.

In spring (reg. 4), significant differences were found between cultivars and between treatments (frost vs non-frost) x sowing time. Analysing frozen and unfrozen plants separately, significant differences were found in frozen plants for sowing time. Results for root growth of frozen plants as the effect of two sowing times in timothy and perennial ryegrass are shown in Figure 2. In winter (reg. 2) root dw as mean values for timothy cvs were 1.33 g and 1.27 g for tillers established in May and July, respectively. In late winter (reg. 3) root dw in the late established (July) timothy decreased to 81% of early established (May) timothy, and in spring (reg. 4) the late established timothy was 142% better than the early established plants. An opposite picture was found in perennial ryegrass. In winter (reg. 2) dw root biomass was 0.56 g and 0.63 g for early vs. late sowing plants. In late winter (reg. 3) early sowing plants obtained 45% of the dw root biomass of the late established perennial ryegrass, decreasing to 37% in spring (reg. 4).

Climatic data for the exp. period
Figure 3 shows the amount of precipitation (mm) and air temperature (ºC) on a monthly basis for Fureneset during the experimental period May 2005 – 2006.

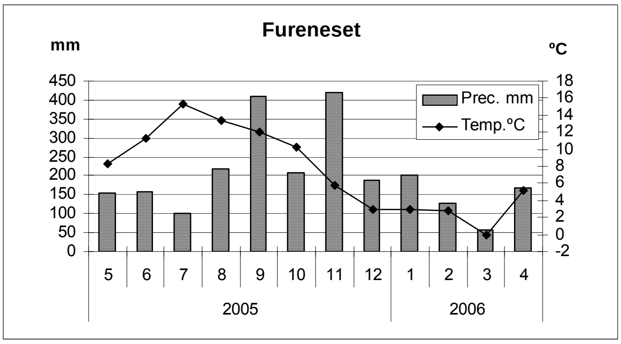

Figure 3. Mean monthly precipitation and air temperature at Fureneset during the period May 2005 – April 2006.

The autumn was very wet, with frequent rain, giving the plants poor hardening conditions. Mid-winter was mild prior to a cold period in late winter and spring.

Discussion

The differences found in the root growth between northern and southern cultivars confirmed the hypothesis for timothy cvs that the northern cultivar Engmo was able to regenerate roots faster than the southern cultivar Grindstad in spring. Higher frost tolerance (Höglind *et al.* 2006) and greater resistance to dehardening at 2ºC (Jørgensen *et al.* 2006) probably contributed to its larger root-regeneration ability. Perennial ryegrass cvs Riikka and Gunne showed less ability to regenerate roots. Riikka, which showed the higher ability to regenerate roots, may be considered as a more winterhardy cultivar than Gunne. Höglind *et al.* (2006) found that Riikka developed a higher level of frost tolerance than Gunne at two out of three sites in Norway. Jørgensen *et al.* (2006) also found that Riikka dehardened more slowly than Gunne at low positive temperatures during winter. Both for frost, ice cover and snow cover Riikka had higher ground cover in spring compared to Gunne in a Nordic study (Pulli *et al.* 1996). There was a trend of decreased root regrowth with increasing overwintering time. This corresponded well to the decrease in frost tolerance from winter to spring (Höglind *et al.* 2006). The fact that frost treated timothy and to a lesser extent perennial ryegrass produced more root dw than untreated plants during winter needs more investigation of the mechanisms behind growth promotion.

Effects of sowing time on root regeneration may probably partly be explained with the content of different carbohydrate fractions. These analyses are in progress.

The experiment has shown that timothy and perennial ryegrass have different root regeneration capacity during winter and spring. Timothy had the highest regeneration capacity. We also found that the root regeneration capacity was affected by sowing time. When exposed to mild frost stress late established plants of both species showed higher root regeneration in spring compared to early established plants.

Acknowledgement

This study was funded by the Norwegian Research Council and Bioforsk as part of the WINSUR project (Climate change effects on winter survival of perennial forage crops and winter wheat and on plant diseases and weed growth and control at high latitudes) 2004-2008.

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Biotechnological tools for breeding feeding quality and optimal growth rhythm in timothy, *Phleum pratense*

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Introduction

Forage grass breeding in Finland concentrates on timothy. The main goal for timothy breeding in Finland is to combine high yield, good winter survival, and high feeding quality. Variety breeding in timothy is based on phenotypic selection of individuals followed by progeny testing and selection of superior parents. Parental clones are combined to form a synthetic variety.

Efficiency of timothy breeding suffers from a small genetic gain per generation. This is mainly due to biological factors, which slow down the breeding process. Timothy is a hexaploid (2n=6x=42), cross-pollinating species. This means high heterozygosity: even six different alleles can reside within one gene locus of a timothy individual. In addition, timothy is a perennial plant and phenotypic testing of each accession in field conditions takes several years.

The aim of our project is to enhance the release of high quality timothy varieties for farmers. In this project an attempt is being made to develop and deploy the newest biotechnological tools for forage breeding, which fastens development of high yielding, high quality forage grass varieties. The specific aims of the project are:

1. Deployment of public sequence databases, comparative genetics and candidate gene analysis for development of DNA marker tools for better digestibility in timothy.
2. Development of a NIR method for determining INDF (indigestible neutral detergent fibre) from timothy breeding samples.
3. Exploitation of the newly developed timothy retrotransposon markers in bulked segregant analysis for developing genetic markers linked to grey snow mold (*Typhula ishikariensis*) resistance.
4. Studying the physiological base of growth rhythm in timothy, especially the importance of carbohydrates in start of growth, regrowth ability and cold hardening.
5. Clarifying the mode of inheritance in timothy.

Feeding quality

Lignification of plant cell walls is the major factor responsible for lowering digestibility of forage tissues as they mature. Lignin synthesis genes are well described and many of them have been sequenced from species other than timothy. We are using specific lignin synthesis genes as candidate genes for digestibility. To study genes affecting feeding quality, we have a progeny between two parental timothy clones, which differ in quality traits. Thus far we have sequenced two genes from timothy: CAD and OMT. We have found several alleles of both genes in both parental clones. Differences are often single nucleotide polymorphisms, many of which affect the amino acid composition of the coded protein. Timothy progeny is tested together with the parents for feeding quality in replicated trials. Quality will be analysed separately from leaf and stem fractions by NIR. We try to relate the gene sequence variation in the progeny to variation in digestibility traits.

In order to use NIR analytics for studying the digestibility traits, 200 selected forage samples have been analysed for their chemical constitution, cellulase digestibility and INDF by traditional means. INDF was determined by incubating the forage samples in rumens of milking cows. Calibration of NIR for determining INDF from the timothy progeny samples is currently ongoing.

Snow mold resistance

A progeny between two parental clones (Tammisto II 39 and Nosappu 91) differing in cold tolerance and snow mold resistance has been tested for resistance against *T. ishikariensis.* Testing was done in specially developed green house conditions. Survival and recovery of the progeny clones was recorded several times. The best eight clones were selected to the resistant bulk and eight poorest to the susceptible bulk. Bulked DNA samples were compared to each others with retrotransposon based markers. Several markers putatively linked to resistance were found. We will test these putative markers in the whole progeny soon and relate their appearance to observed snow mold resistance.

Growth rhythm

Ten progeny clones representing different levels of snow mold resistance have been selected for further studies of growth rhythm and cold tolerance. The clones have been multiplied and planted in field conditions. During the following two years these will be surveyed for their start of growth, first and second cut yield, regrowth ability and tillering. At certain developmental phases samples for analysis of reserve and soluble carbohydrates as well as key enzymes in carbohydrate metabolism will be collected. Plants will also be tested for their cold tolerance in laboratory conditions.

Mode of inheritance

We have tested the inheritance of codominant SSR markers in a controlled cross between individual timothy clones. In the progeny 5-8 alleles were detected in each SSR locus. Inheritance seems to be complex but due to some inconsistencies in the data the exact mode of inheritance can not be determined.

Effects of the earliness of two different cultivars of timothy on the quality of swards at different cutting sequences

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Introduction

The harvest is often delayed because of bad weather. This can be a problem since the quality of the swards decreases rapidly if not harvested in time. To feed milking cows and growing cattle it is necessary to use high quality swards. There are in general only two or three days when the quality is the best. Delaying harvesting in central Sweden will allow only two cuts a year instead of three cuts a year, which will also affect which cultivar or species to choose.

To study the effect of different cultivars of timothy together with different cultivars of clover we were interested to see if it is possible to lengthen the period of harvest yet keeping a good quality and yield.

This project was financed by Försök – I – Väst and Milko.

Materials and methods

The field trial was situated in the Middle West part of Sweden, Värmland, where grassland is the dominating crop. Ryegrass is possible to grow but will not always cope with the cold winter, resulting in an infection of weeds . We therefore chose to grow the two different cultivars of timothy, Grindstad and Ragnar, with meadow fescue, two cultivars of red clover and one cultivar of white clover. Four of the mixtures of seeds were chosen so as to be early maturing and two as late maturing. Grindstad was combined with Fanny, with or without meadow fescue. Ragnar was combined with Jesper, considered a late cultivar of red clover. Three of the mixtures were with clover and three without. In the late mixtures there was no meadow fescue since there is no cultivar that is late enough (Table 1).

Table 1. Mixture of seeds tested.

Species/variety	A "early" kg ha^{-1}	B "early" kg ha^{-1}	C "late" kg ha^{-1}	D "early" kg ha^{-1}	E "early" kg ha^{-1}	F "late" kg ha^{-1}
Timothy						
Ragnar			12			16
Grindstad	8	12		10	16	
Meadow fescue						
Sigmund	8			10		
Red clover						
Jesper			2			
Fanny	2	2				
White clover						
Ramona	2	2	2			
Total, kg ha^{-1}	20	16	16	20	16	16

Both the early and the late mixtures were cut two or three times a year. Harvesting in 2005 took place on 9 June, 21 July and 5 October, in the case of three cuttings, and on 20 June and 8 August in the case of two cuttings. Fertilization depended on the rate of clover in the mixture (Table 2).

Table 2. Nitrogen fertilization, kg ha^{-1}

	1st cut	2nd cut	3^{d} cut
Three cuts a year			
A B C	60	50	40
D E F	100	80	60
Two cuts a year			
A B C	60	50	
D E F	100	80	

Results from the first year

In the case of the first year, 2005, the total yield varied from 9490 kg ha^{-1} to 11740 kg ha^{-1}, as shown in Table 3. The between mixture difference in the dry matter yield was significant, but not between two or three cuttings a year.

Table 3. First year yield of the mixtures tested, kg ha^{-1}

	Yield, kg DM ha^{-1}				
	1st cut	2nd cut	3^{d} cut	total	Relative yield
A early, three cuts	5530	3280	2930	11740	100
B early, three cuts	5190	3380	2780	11340	97
C late, three cuts	4750	2890	2530	10170	87
D early, three cuts	5000	2450	2440	9890	84
E early, three cuts	4970	2750	2360	10080	86
F late, three cuts	4680	2600	2210	9490	81
A early, two cuts	8380	3350		11730	100
B early, two cuts	7720	3540		11250	96
C late, two cuts	6880	2740		9620	82
D early, two cuts	8010	2870		10870	93
E early, two cuts	7260	2730		9990	85
F late, two cuts	6880	2820		9700	83
LSD[1] harvest	240	ns	ns	ns	
LSD mixtures	410	230	ns	480	

[1] LSD = Least significant difference between means

The energy content presented in Table 4 is relatively low. The effect of clover on the energy content was not considered, which is why straw with a high clover content was misjudged. The content of NDF and proteins was affected by the clover content, resulting in a higher protein level and a lower level of NDF. There was not much difference in the quality between the early and the late cultivars, though there might have been a slight tendency for a better quality in the late mixtures then in the early. The late mixtures would then be a better choice with two cuts a year.

Results from the second and following years

For the seminar in Iceland we will be able to show some interesting results also from the second year (2006), such as level of dry matter yield from the first cutting.

The field trial will continue for a third year. We have also had opportunity to start another similar field trial in 2006 which also contains the timothy cultivar Jonatan.

The results from 2006 will be presented in "Mellansvenska försöksrapporten 2007" which you can order from the writers of this abstract in January 2007.

You can also look up the results on www.ffe.slu.se

Tabel 4. Feed quality of the mixtures tested, first year of harvest.

	Digestable energy, MJ kg^{-1} DM			NDF-fiber, g kg^{-1} DM			Raw protein, g kg^{-1} DM		
	1st cut	2nd cut	3d cut	1st cut	2nd cut	3d cut	1st cut	2nd cut	3d cut
A early, three cuts	9.5	9.6	10.2	593	517	486	144	166	138
B early, three cuts	9.1	9.5	9.5	593	530	443	147	160	157
C late, three cuts	9.4	9.7	9.5	589	481	410	157	173	173
D early, three cuts	10.5	10.2	11.4	632	582	555	142	142	96
E early, three cuts	9.8	9.6	11.1	659	610	571	139	135	98
F late, three cuts	10.0	9.8	10.3	646	613	557	138	142	116
A early, two cuts	9.1	9.7		558	513		147	179	
B early, two cuts	9.0	9.5		612	503		129	176	
C late, two cuts	9.3	10.1		589	462		137	198	
D early, two cuts	9.3	10.3		653	598		99	141	
E early, two cuts	9.2	10.5		669	600		95	136	
F late, two cuts	9.7	10.2		670	611		105	141	
LSD[1] system of cuts	0.2	0.2	ns	ns	ns	ns	10	7	ns
LSD mixtures	0.4	0.4	ns	26	30	91	15	12	43

[1] LSD = Least significant difference between means

One year grasslands (without timothy) compared to three year grasslands (with timothy) regarding quantity, forage quality and economy

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Background

In Sweden production of silage is mainly carried out on swards lasting for three years or in many cases longer, with timothy as an important grass in the mixtures. Long-lasting swards can often lead to a decreased content of red clover over the years and an increased weed infestation which may cause large and undesired variations in both dry matter yield and in forage quality between years and between individual cuts.

The aim with this study was to compare intensively cut swards lasting for one year with swards lasting for three years with timothy included. In the one-year leys species were used that have a high dry matter yield potential but that are more sensitive to climate in respect to over-wintering. The one-year swards were repeatedly incorporated and re-established every second year in the crop rotation. Dry matter yield, forage quality and the economy of the two systems were determined.

Materials and methods

Three field experiments were carried out in two different locations (Rådde and Uddetorp) in western Sweden and were established in 2001 and 2002. The leys were established by under-sowing sown cereals in spring . The three-year grasslands (treatments C and D) were established with a fully grown cereal and the system with one-year swards was established in a cereal grown as forage, cut about two weeks after ear emergence. One-year leys (treatments A and B) were cut four times each year and three-year leys were cut three times. Swards lasting for one year were then tilled in the following autumn or spring and then again established as described. The experiments were carried out with four replicates. Yields were quantified in all plots for all crops in the rotations, also in forage of cereal and re-growth of the grassland (the year of establishment). Treatment-wise analyses of quality and botanical compositions were carried out each year. The species in the seed mixes were chosen by Svalöf Weibull AB and Scandinavian Seed AB (Table 1).

Table 1. Seed mixtures in the four treatments.

Swards lasting one year	Swards lasting three years
Treatment A: 15% red clover *Fanny*, 45% festulolium *Paulita*, 40% hybrid ryegrass *Roxy* (SW)	**Treatment C**: 30% timothy *Alexander*, 30% meadow fescue *Mimer*, 20% perennial ryegrass *Helmer*, 10% red clover *Sara*, 10% white clover *Sonja* (SW 944)
Treatment B: 60% hybrid ryegrass *Pirol*, 40% italian ryegrass *Fabio* (SSd). In 2002 red clover was included in the mixture.	**Treatment D**: 10 %timothy *Lischka* + 10 % *Liglory*, 10 %meadow fescue *Preval*, 30% festulolium *Prior*, 10% perennial ryegrass *Herbie* + 10% *Fanda*, 6% red clover *Titus* + 4 % *Rajah*, 5 % white clover *Riesling* + 5% *Abercrest* (SSd)

The results were evaluated with a model designed for calculating economical results per ha. The purpose of this model is to make it possible to evaluate different silage qualities from field experiments with all measured variables included and thereby report the results in a clearer and more instructive way (Gruvaeus, unpublished). The program optimizes the cheapest feed ratio and the value of different silages is stated against a defined standard quality of silage (value/price for 1 MJ in barley).

Treatments A and B were fertilized with 100+80+70+50 = in total 300 kg nitrogen ha^{-1} and C and D were fertilized with 80+70+50= 200 kg N ha^{-1}. The cost of each year as grassland was estimated according to figures shown in Tables 2 and 3. The harvesting cost was then estimated depending on the amount of forage.

Table 2. Expenses in treatment A and B.

Expenses		Quantity	Price	SEK ha^{-1}
Sowing	100 %			300
Seed	100 %	18	28.00	504
Nitrogen Axan 27-4	kg ha^{-1}	815	2.30	1874
Nitrogen N-34	kg ha^{-1}	235	2.45	576
Cost of fertilizing				305
Cost per year of ley except harvest Treatments A and B				3559

Table 3. Expenses in treatment C and D.

Expenses		Quantity	Price	SEK ha^{-1}
Sowing	33 %			66
Seed	33 %	18	28.00	199
Nitrogen Axan 27-4	kg ha^{-1}	740	2.30	1704
Cost of fertilizing				224
Cost per year of ley except harvest Treatments C and D				2193

Results and discussion

The forage produced from each growing system was included in the summary of both yield and income. The one-year sward yields over the period of three years produced nearly 36 Mg dry matter (DM) ha^{-1} in the experiment at Uddetorp and over 29 and 24 Mg DM at Rådde In the same experiments, the three- year swards produced almost 31 Mg DM at Uddetorp and over 26 and 23 Mg DM at Rådde.

The difference in gross income (except for the higher cost for tillage in A and B) for each year with grassland was 3700 SEK ha^{-1} at Uddetorp, or to the good for the short-lived swards. The experiments at Rådde showed the opposite result. At Rådde, the three-year swards showed the highest income and the difference in gross income was -300 and -1 400 SEK ha^{-1}. The reason was probably the more difficult winter conditions at Rådde compared to Uddetorp. These comparisons were based on two replicates per system.

The system with one-year leys is therefore possibly feasible in a small part of Sweden where there is little or no problem with winter conditions. There must also be fields with little or no problems with stones, in other words in a very small part of Sweden. For the major part of Sweden timothy still plays an important role in the grasslands.

A simple grass growth model for timothy, tested in Iceland and Norway

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A simple grass growth model for timothy was tested at six different locations, four in Norway and two in Iceland. There are five types of climate seen at these six locations. The purpose was to investigate which weather conditions – temperature, precipitation, wind, sunshine, radiation, cloud cover, humidity and soil water – had the largest impact on grass growth at each location. The period studied was April to August in 1991 to 1995. Prior to the model runs, the first day of growth was found, i.e. the day in spring when the mean day temperature for the previous 5 days had been higher than 5°C and there was no snow cover on the ground. Then the sum of the mean temperatures were calculated from the day of start of growth. Most cases which were tested had fewer growth days than normal and the sum of the day temperatures in the growth period was lower.

The results showed that precipitation had the largest influence on the growth rate in the beginning of the period in S Norway and in mountain Norway. However in W and N Norway sunshine and temperature in spring had the largest effect because precipitation is normally sufficient there. In Iceland the temperature in spring was the main factor. When the temperature rose in summer and precipitation was sufficient the growth rate started rapidly. The largest grass production in Iceland was retrieved when there was a lot of sunshine along with enough precipitation.

Lack of precipitation in Norway in mid-summer can cause a mid-summer depression, in spite of sufficient temperature and sunshine. This was not observed in Iceland.

The study indicated that precipitation was the largest climatic factor in agricultural meteorology. The amount of precipitation and its distribution during the growth period had the largest influence in most places, in addition to sufficient temperature. Hence, along with precipitation, temperature was also a big climatic factor. Cold springs and low precipitation in late summer resulted in a low grass growth rate.

The model can be used to forecast grass growth in summertime, based on statistical information from crop measurement at the site and the weather conditions in spring and the beginning of summer each year.

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The consequence of harvesting regime on spring growth, yield and persistence in timothy the following year

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Introduction

It is well established that timing of the first harvest has a pronounced effect on timothy persistence in Icelandic grass fields (Hermannson & Helgadóttir 1991, Sveinsson 2003). It has also been noted from a series of experiments that spring growth in timothy is affected by the harvesting regime from the previous year (Brynjólfsson 1994).

The objective of this poster is to evaluate from three experiments the consequences of harvesting regime on spring growth, yield and persistence in timothy the subsequent year.

Materials and methods

All three experiments were located at the Agricultural University of Iceland in Hvanneyri in SW Iceland (64°34'N, 21°46'W, 12.4 m above sea level).

Experiment 1 (series no 826-96) was a variety trial in timothy with two cutting treatments (two cuts vs. one cut per season). The first harvest year was 1997. In June 15 1998 grass height was measured in plots with a standard grass plate meter to evaluate treatment effects on spring growth.

Experiment 2 (series no 831-96) was initiated to study the effect on harvesting regimes on yield and yield composition in timothy (*var.* Adda)/red clover (*var.* Bjursele) mixtures. Chemical fertilizer applied in 1997 amounted to 33 kg N, 20 kg P and 80 kg K ha^{-1}. The red clover totally perished during the first winter. However, the plots were cut anyway according to the experimental plan in 1997 and 1998. In June 15 1998 grass height was measured in plots with a standard grass plate meter to evaluate treatment effects on spring growth.

Experiment 3 (series no 833-96) was initiated to study the effect on harvesting regimes on dry matter (DM) yield and persistence in timothy (*var.* Adda). The experimental layout was identical with experiment 2. In June 15 1998 grass height was measured in plots with a standard grass plate meter to evaluate treatment effects on spring growth and on 21 July timothy cover was estimated in plots to estimate timothy persistence.

Results

Results from all three experiments show that harvesting regime in timothy has a substantial effect on spring growth, DM yield and persistence the following year.

Spring growth

Results from experiments 1, 2 and 3 are tabulated in Tables 1 and 2.

In experiment 1 (Table 1) spring growth was remarkably reduced in timothy if cut twice instead of once in the previous growing season. The effect was also similar across the eight cultivars tested even though the spring growth was variable between cultivars. The northernmost cultivars clearly showed faster spring growth than the more southern cultivars.

The effect of two cuts in the previous growing season on spring growth was verified in experiments 2 and 3 (Table 2). These experiments also revealed that an early first cut followed by a delayed second cut was more detrimental than an early second cut, which might have been due to the fact that an early second cut allows the plants to prepare better for the winter than plants cut later in the season.

Table 1. The effect on two different harvesting regimes on timothy growth in the spring of the following year. Exp. 1. Residual standard error of means 7.7 mm.

Treat-ments[1]	Cultivar								
	Nor1	Adda	Jonatan	Bodin	Grindstad	Vega	Iki	Tukka	Mean
	--- timothy grass height, mm on June 15 1998 ---								
I	136	142	100	142	53	137	119	98	116
II	189	173	140	184	81	172	177	141	157

[1] I = two cuts in 1997, June 10 and August 24, II = one cut in 1997 on 27 July.

Table 2. The effect on different harvesting regimes on timothy growth in the spring of the following year. Experiments 2 and 3. Residual standard error of means in Experiment 2, 7.6 mm and in Experiment 3, 6.3 mm.

	2nd cut in 1997				
1st cut in 1997	Aug-15	Aug-25	Sep-02	no 2nd cut	Mean
	--- grass height, mm on June 15 1998, exp. 2[1] ---				
Jul-01	85	74	69		74
Jul-14		87	101		94
Jul-21				118	118
	--- grass height, mm on June 15 1998, exp. 3[2] ---				
Jul-01	140	120	94		112
Jul-14		134	112		123
Jul-21				181	181

[1] Experiment 2. Plots receiving 33 kg N, 20 kg P and 80 kg K ha^{-1} in 1997

[2] Experiment 3. Plots receiving 120 kg N, 20 kg P and 80 kg K ha^{-1} in 1997

The timing of the first cut was also a factor in the persistence of timothy. This was probably because the regrowth of early cut timothy consisted mostly of generative shoots, which do not prepare for winter, while regrowth in late cut timothy consisted of vegetative shoots, which do prepare for the winter.

Dry matter yield

In experiments 2 and 3 DM yield was measured on 21 July 1998 (Table 3). The results resembled the spring growth measurements in Table 2. Two cuts the previous year substantially reduced DM yield in the first cut the following year in experiment 2 but to a lesser extent in experiment 3. In addition, a delayed second cut after an early first cut the previous year seems to have had an additional negative effect on subsequent DM yield in experiment 2 but only vaguely in experiment 3.

Table 3. The effect on different harvesting regimes on timothy DM yield in 1st cut the following year. Experiments 2 and 3.

	2nd cut in 1997				
1st cut in 1997	Aug-15	Aug-25	Sep-02	no 2nd cut	Mean
	--- DM yield, t ha^{-1} on July 21 1998, exp. 2[1] ---				
Jul-01	5.19	4.45	4.29		4.64
Jul-14		4.84	4.88		4.86
Jul-21				6.07	6.07
	--- DM yield, t ha^{-1} on July 21 1998, exp. 3[2] ---				
Jul-01	6.12	6.55	5.77		6.15
Jul-14		6.19	5.78		5.98
Jul-21				6.82	6.82

[1] Experiment 2. Plots receiving 33 kg N, 20 kg P and 80 kg K ha^{-1} in 1997

[2] Experiment 3. Plots receiving 120 kg N, 20 kg P and 80 kg K ha^{-1} in 1997

It was also possible in these two experiments (2 and 3) to compare the yield on 1 July 1998 from plots that had been cut either twice or once in the year before (Table 4).

Table 4. DM yield 1 July 1998 in experiments 2 and 3.

	Cutting regime in 1997		
Experiment	1 July and 15 August	21 July only	Difference
	--- DM yield, t ha^{-1} ---		
2	2.57	3.91	1.34
3	3.71	5.12	1.41

According to Table 4, the consequences of two cuts from the previous year were revealed early in the growing season but evened out when timothy reached a maximum DM yield on 21 July, most likely because the timothy in plots that were cut only once in 1997 had reached ceiling yield, causing lodging, before it was cut on 21 July in 1998.

Persistence

Harvesting regime has a clear and well established effect on timothy persistence in grass fields, as has been noted. When timothy perishes from the sward it is replaced by other lower yielding grass species, at least to begin with.

The winter of 1997 to 1998 at Hvanneyri was clearly harsh for forage plants sown in 1997. It is acknowledged that high rates of N fertilizer can cause winter kill in grasses. This seems to have been the case when timothy persistence is compared between experiments 2 and 3. Timothy in experiment 2 receiving only 33 kg N ha^{-1} in 1997 had no winterkill and amounted to 95% of harvested DM yield in 1998 irrespective of harvesting treatments in 1997. In experiment 3, on the other hand, where timothy had received 120 kg N ha^{-1} in 1997 the winter kill was pronounced and dependent on harvesting regimes in 1997 (Table 5).

Table 5. The effect on different harvesting regimes in 1997 on timothy proportion in DM yields 21 July 1998. Experiment 3.

	2nd cut in 1997				
1st cut in 1997	Aug-15	Aug-25	Sep-02	no 2nd cut	Mean
	--- timothy proportion (%) of DM yield ---				
Jul-01	75	85	50		70
Jul-14		78	60		69
Jul-21				93	93

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Morphological and qualitative changes in growing timothy

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Introduction

This poster presents a part of a project which was submitted as a thesis by Lárus Pétursson in 1995 to the Agricultural University in Iceland in partial fulfilment of the requirements for the Degree of Bachelor of Science

Materials and methods

In 1994 samples of timothy plants, *var.* Engmo were harvested at regular intervals throughout the growing season in a grass field located at the Agricultural University of Iceland in Hvanneyri in SW Iceland (64°34'N, 21°46'W, 12.4 m above sea level). Samples were taken at weekly intervals from 15 June to 17 August totalling 10 samples.

The grass samples were sorted into generative shoots and vegetative shoots. The vegetative shoots were further sorted into green and wilted leaves and the generative shoots into photosynthetic (green) and non photosynthetic (yellow) leaves, stems and inflorescence. The leaf sheaths were sorted as leaves. Shoots were classified as vegetative until the head (inflorescence) started to swell in the sheaths just prior to head emergence. This explains the swift shift from vegetative to generative form in the results.

On three sampling dates, 29 June, 13 July and 27 July, shoots were further divided into internodes and leaves were separated into laminae and sheaths. In generative shoots the first internode is just beneath the inflorescence and includes the flag leaf and the latest (the 5th) internode is at the base.

All sorted parts were oven dried and weighed to determine their proportion of total dry matter (DM) weight. If samples were big enough they were analysed for nitrogen (N) and digestible organic matter determination (DOM) by Kjeldalh and Cellulase procedures, respectively.

Results

Morphology

The changes observed in morphology with progressing growth stages in timothy *var.* Engmo are tabulated in Tables 1 and 2.

Table 1. Relative size (% of total DM) of different plant parts in 'Engmo' timothy in 1994.

	Sampling dates									
	15-Jun	22-Jun	29-Jun	06-Jul	13-Jul	20-Jul	27-Jul	03-Aug	10-Aug	17-Aug
Vegetative shoots;										
-green leaves	98	99	97	15	21	11	18	15	17	17
-wilted leaves	2	1	3	1	1	1	0	1	1	1
Generative shoots;										
-green leaves	-	-	-	63	42	41	30	27	21	16
-yellow leaves	-	-	-	1	1	1	1	3	3	4
-stems	-	-	-	17	26	33	38	41	44	47
-inflorescence	-	-	-	3	9	13	13	13	14	15

There were no measurable generative shoots before 29 June, which means that stems and inflorescence tissue prior to this date were too small to be sorted out. From 29 June to 6 July there was a great shift from vegetative to generative shoots which had become 80% of total DM weight with stems accounting for 10%. This proportion between generative and vegetative shoots remained unchanged throughout the growing season while the stem proportion within the generative part increased steadily. At the latest sampling date (17 August) the stem had become almost 50% and inflorescence 15% of the total generative weight (Table 1).

The relative DM proportion of different internodes with progressing growth stage in timothy is tabulated in Table 2.

Table 2. Relative size (% of total DM) of different internodes in 'Engmo' timothy in 1994.

	Sampling dates				
	29 June	13 July		27 July	
	Types of shoots				
Plant division	"vegetative"	vegetative	generative	vegetative	generative
	--- relative size (%DM) of total weight ---				
Inflorescence	0.9		7.3	-	13.9
1st internodes					
-green leaf laminae	8.3	1.0	2.9	0.6	2.5
-green leaf sheath	0.6	1.1	6.1	0.5	6.5
-stem	-	0.1	1.7	0.1	5.3
2nd internodes					
-green leaf laminae	19.8	2.7	7.7	1.2	6.2
-green leaf sheath	6.5	1.6	6.7	0.7	6.0
-stem	0.1	0.4	2.6	0.6	9.9
3d internodes					
-green leaf laminae	22.1	3.1	7.6	1.3	5.4
-green leaf sheath	13.8	1.7	6.2	0.7	5.0
-stem	0.5	1.7	7.4	1.0	12.4
4th internodes					
-green leaf laminae	11.4	2.0	4.6	1.0	1.8
-wilted leaf laminae	-	0.2	0.5	-	0.9
-green leaf sheath	7.6	1.3	3.6	0.5	1.8
-stem	3.3	2.8	9.0	1.3	8.5
5th internodes					
-green leaf laminae	2.5	0.6	0.6	0.6	0.1
-wilted leaf laminae	0.5	0.2	0.5	0.1	0.3
-green leaf sheath	1.1	0.3	0.4	0.3	0.2
-wilted leaf sheath	0.3	-	0.2	-	-
-stem	0.8	1.2	2.2	1.3	1.5
Total	100	22.1	77.9	11.8	88.2

The stem proportion of the total DM weight was only 5% on June 29 even though all shoots had then in fact become generative because all "vegetative" shoots were elongated. What keeps the plants erect are the leaf sheaths, which accounted for 30% of the total DM weight on 29 June. Two weeks later, when almost all generative shoots were headed, leaf sheaths still weighed more than stems on the first two internodes. On the third and fourth internodes their weights were similar but on the fifth internodes the weight was almost entirely on the stem. However, the fifth internodes were always very short and were only a small part of the total DM weight of the plant.

On the last sampling date on 27 July the leaves were still green at the first three internodes and the sheath on the flag leaf (first internodes) weighed more than the stem.

Protein content

The observed changes in protein content in plant parts with progressing growth stages in timothy *var.* Engmo are tabulated in Table 3. The protein content in vegetative shoots in the beginning was approximately 22% of DM weight but declined within only 4 weeks down to 10%. After that the protein content remained steady in the generative leaves but continued to decline down to 8% in the vegetative leaves. The protein content in stems was only 8% of DM weight when the stem was first measurable on 6 July and declined steadily down to 3%. The protein content of the inflorescence was 25% of DM weight when first measurable on 6 July, declined down to 14% in two weeks and remained steady after that.

Table 3. Crude protein content in DM (%) of different plant parts in 'Engmo' timothy in 1994

	Sampling dates									
	15-Jun	22-Jun	29-Jun	06-Jul	13-Jul	20-Jul	27-Jul	03-Aug	10-Aug	17-Aug
Vegetative shoots;										
-green leaves	22.5	16.5	12.8	11.6	10.9	10.5	8.6	7.9	6.9	7.7
Generative shoots										
-green leaves	-	-	-	11.6	10.9	10.7	9.9	9.7	10.2	10.2
-stems	-	-	-	8.4	6.1	5.3	4.5	3.9	3.4	3.5
-inflorescence	-	-	-	25.1	16.3	13.3	12.7	12.5	13.9	13.7

Digestible organic matter

The observed changes in digestibility in plant parts with progressive growth stages in timothy *var.* Engmo are tabulated in Table 4. The digestible organic matter (DOM) on the first three samplings dates, which consisted mostly of vegetative leaves, was very high. After that DOM dropped quickly, with the exception of the inflorescence. It is noteworthy that DOM in leaves on generative shoots also became very low with age. This was possibly caused by fast cell wall thickening in leaf sheaths, whose role is to support weak straws.

Table 4. Digestible organic matter (%) of different plant parts in 'Engmo' timothy in 1994

	Sampling dates									
	15-Jun	22-Jun	29-Jun	06-Jul	13-Jul	20-Jul	27-Jul	03-Aug	10-Aug	17-Aug
Vegetative shoots;										
-green leaves	93	89	88	75	66	67	67	71	68	71
Generative shoots										
-green leaves	-	-	-	75	66	68	66	67	63	64
-stems	-	-	-	77	60	56	57	56	55	51
-inflorescence	-	-	-	-	78	70	62	62	67	66

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