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Timothy productivity and forage quality

- possibilities and limitations -

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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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