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Quality of herbage at different latitudes

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Summary

In a cooperative experiment yield and herbage quality of timothy (*Phleum pratense* L.) was measured during the uninterrupted growth of the first cut at 6 latitudes (51 to 69 °N). Rate of production was greatest at Tromsö (69 °N), apparently because of the long day and rapid reproductive development. Digestibility of organic matter declined faster at higher latitude, because stem development proceeded faster and because less leaf dry matter was produced.

However paradoxically, at the same morphological stage, digestibility of the whole crop was better at higher latitude because of the better digestibility of the cell walls from the stems. Presumably rate of lignification could not keep pace with the rapid rate of stem development. So Scandinavian herbage can have a very good quality, despite its stemminess.

Introduction

In discussions it has been suggested that quality of herbage does not deteriorate with age as rapidly in Scandinavia as it does in more southerly Western Europe. If this be true, there might be several reasons for this.

Growth and nutritive value of herbage is affected by many external factors such as temperature, solar radiation, fertilizer, water supply, and also heritable factors such as velocity of reproductive development in spring. Lower temperature at higher latitude may cause less lignification and slower ageing as has often been found in greenhouse studies (e.g. Deinum & Dirven, 1975). Van Soest et al. (1978) also suggested that differences in temperature might be responsible for different ageing patterns at different latitudes. High solar radiation and high nitrogen supply would promote herbage production, without much effect on ageing and digestibility. In addition, growing season is shorter at higher latitude, so genotypes adapted to such climates complete their reproductive cycle and age faster too. So various degrees of ageing are possible.

The pattern of ageing in spring normally proceeds as follows. At first there is little or no decline of digestibility with age, as it is still rather cold and only leaves are formed. Then during stem elongation and reproduction digestibility declines rapidly and almost rectilinearly with time. After reproduction, herbage dry mass is about 8-10 tonnes/ha and digestibility is low. It may decline a little more with age during ripening of the seed, or in occasional conditions digestibility may increase somewhat because new tillers emerge through the lodged crop. In this paper, most attention will be paid to the rapid decline in the rectilinear phase of ageing in spring.

Several papers on digestibility of grasses show such a decline in digestibility with age. In this paper, we restrict ourselves to timothy (*Phleum pratense* L.) and Table 1 presents some data on ageing collected from literature. Some results refer to digestibility in vivo, others to measurements in vitro, perhaps corrected with standard samples to digestibility in vivo. The decline is similar to that of other grasses. However digestibility sometimes declined a little slower with age than in other grasses (e.g. Minson et al., 1964), sometimes a little faster (Nowruzian, 1977).

There is a tendency for decline with age to increase with latitude, late varieties

Table 1. Average decline in apparent digestibility of organic matter in timothy at different sites during the rectilinear phase of ageing.

Site	Latitude (°N)	vivo or vitro	Decline (% d^{-1})	Reference
Clermont-Ferrand (FR)	44	vivo	0.40	Weiss et al. (1970)
Nova Scotia (CA)	46	vitro	0.64	Calder & MacLeod (1968)
Nova Scotia (CA)	46	vitro	0.7-0.8	Kunelius et al. (1974)
Giessen (DE)	51	vitro	0.45	Nowruzian (1977)
Hurley (GB)	51	vivo	0.41	Minson et al. (1964)
Hurley (GB)	51	vitro	0.39	Terry and Tilley (1964)
Hurley (GB)[1]	51	vitro	0.34	Green et al. (1971)
Hurley (GB)[2]	51	vitro	0.23	Green et al. (1971)
Wageningen (NL)	52	vitro	0.44	Jongbloed (1973)
Wageningen (NL)	52	vitro	0.44	van Empel (1974)
Oslo (NO)	59	vivo	0.47	Homb (1953)
Helsinki (FI)	58	vitro	0.57	Huokuna (1978)
Uppsala (SE)	59	vivo	0.49	Kivimäe (1966)
Uppsala (SE)	59	vivo	0.52	Kivimäe (1959)

[1] Early varieties
[2] Late varieties

showing a smaller decline than early-flowering varieties. In Canada ageing is much greater than in maritime Europe, possibly because of the steeper rise of temperature in Canada. So there seems to be a conflict between the suggestion in the first sentence of this paper and the published results, which indicate that ageing often proceeds faster at higher than at lower latitude.

To test the validity of the suggestions and to trace the origin of the contradiction a cooperative experiment was performed at various latitudes in 1977 and 1978. The results are summarized below.

Materials and methods

Timothy (*Phleum pratense* L.) was selected as a grass species that would produce efficiently at all sites. The best cultivar was chosen for each region.

Sites

Sufficiently large fields were available at each site (Table 2) for proper harvest of random samples on the various sampling dates.

The field in Wageningen was accidently cut on 13 May 1977, but a replacer was found at Ghent (Belgium) with the same variety. Samples from Ghent were taken from 3 June 1977 onwards. Since grass growth started at about the same time and herbage quality would be equally high in a young stage, it seemed justifiable to associate data for Wageningen and Ghent in 1977 in the lines of the various figures. The trial in Wageningen was repeated in 1978.

Yield and morphological composition

Only first growth was studied. During this uninterupted growth, herbage was sampled at intervals of 7 to 14 days. Five to ten samples of quadrats 0.25 × 0.25 m were cut at about 5 cm height. Sampling periods were not equally long at all sites however (from 44 days at Uppsala to 73 days at Wageningen/Ghent).

Fresh and dry weight were measured at each sampling date and proportion of leaf blade, leaf sheath + stem and dead material. Dehydration was at 70 °C in forced ventilated ovens and samples were ground to pass a 1-mm sieve.

Table 2. General information on the various sites and on fertilizers applied.

Site	Year	Latitude (°)	Cultivar	Soil Type	Fertilizers ($kg\ ha^{-1}$)		
					N	P	K
Ghent (BE)	1977	51	Erecta	sand	80	51	120
Wageningen (NL)	1977	52	Erecta	clay	140	32	124
Wageningen (NL)	1978	52	Erecta	clay	100	29	75
Landskrona (SE)	1977	56	Kämpe II	loam	84	36	102
Uppsala (SE)	1977	59	Kämpe II	clay	100	49	91
Umeå (SE)	1977	64	Engmo	silt loam	80	35	75
Tromsö (NO)	1977	69	Engmo	peat	100	43	115

Chemical composition
All chemical analysis was at Wageningen.

The morphological fractions were analysed for Kjeldahl-N, ash and water-soluble carbohydrate (wsc) with ferricyanide on an automatic analysing device. Organic cell-wall constituents (cwc) and digestibility in vitro of organic matter (D_{vitro}) for ruminants were estimated by the methods of Goering & van Soest (1970). Apparent (D_{om}) and true digestibility ($D_{om\ true}$) in vivo of organic matter could be calculated from D_{vitro} of standard samples of known D_{om} and $D_{om\ true}$. Digestibility of cell-wall contituents (D_{cwc}) could be calculated from content of cwc and $D_{om\ true}$, as digestibility of cell contents (100 − cwc) was considered complete.

This fractionation into morphological and chemical constituents, and their digestibility allow easy discovery of the factors responsible for differences in forage quality at the different latitudes.

Meteorological data
Table 3 presents weather data, averaged for each month. It shows the longer days at higher latitude. Solar radiation was low in the maritime climates of Wageningen/Ghent and of Tromsö, but higher in the more continental sites in Sweden. Temperature declined with higher latitude as expected; again, temperature was somewhat higher in continental parts of Sweden. Water supply was seldom limited.

Fertilization
Sufficient fertilizer was applied at all sites (Table 2), so that rate of production was not hampered by mineral supply.

Results and discussion

Table 4 presents some general information on production and chemical composition of the herbage at the different sites.

Table 3. Metereological data of the sites.

Site	Year	Daylength* (h)				Average daily solar radiation ($MJ\ m^{-2}\ d^{-1}$)				Average daily temperature (°C)			
		May	June	July	Aug.	May	June	July	Aug.	May	June	July	Aug.
Ghent	1977	16.3	17.2	16.7	15.3	16.7	13.4	16.3	13.2	11.9	13.8	17.1	15.7
Wageningen	1977	16.4	17.3	16.8	15.4	17.6	14.2	15.6	12.6	11.9	14.6	16.7	16.2
Wageningen	1978	16.4	17.3	16.8	15.4	15.3	16.9	15.5	13.5	12.7	15.1	15.3	15.1
Landskrona	1977	17.2	18.4	18.0	16.0	19.9	18.9	16.9	14.5	11.8	16.1	16.1	15.6
Uppsala	1977	18.2	19.5	19.0	16.4	18.8	21.1	15.3	14.9	9.9	14.6	14.1	14.4
Umeå	1977	19.3	22.0	20.4	17.2	16.5	20.3	15.7	15.1	6.2	12.2	13.8	13.0
Tromsö	1977	23.4	24.0	24.0	19.0	15.2	14.3	15.1	12.2	3.3	7.2	11.8	11.4

* Daylength is the time between sunrise and sunset + 1 hour, except where the sun did not set. The values are hours and decimal fractions.

Table 4. Average rate of dry-matter production during rectilinear growth and average chemical composition of timothy at the different sites (means of the different sampling dates).

Site	Sampling period	Rate of production of dry matter ($g\ m^{-2}\ d^{-1}$)	Content of dry matter (%)				Digestibility	
			N	wsc	ash	cwc	om	cwc
Wageningen/Ghent	2 May-14 July	19.3	1.99	8.9	6.4	62.4	68.4	53.4
Wageningen 1978	26 April-19 June	13.4	1.97	7.4	7.6	57.8	77.5	64.0
Landskrona	9 May-27 June	15.5	3.27	10.1	10.4	50.1	77.0	58.4
Uppsala	19 May-1 July	14.3	2.17	14.7	7.4	52.2	76.0	57.4
Umeå	6 June-26 July	18.6	2.00	12.1	7.4	58.3	73.3	57.6
Tromsö	27 June-15 August	25.1	1.63	13.8	5.5	60.1	71.0	54.4

Sampling at Wageningen/Ghent in 1977 was over a much longer period then elsewhere. This and the few samplings of the early stages of growth caused the low average digestibility.

Dry-matter production

Average rate of dry-matter production during rectilinear growth ranged from 13 to 19 $g\ m^{-2}\ d^{-1}$ (Table 4), which is in fair agreement with the rates normally found in

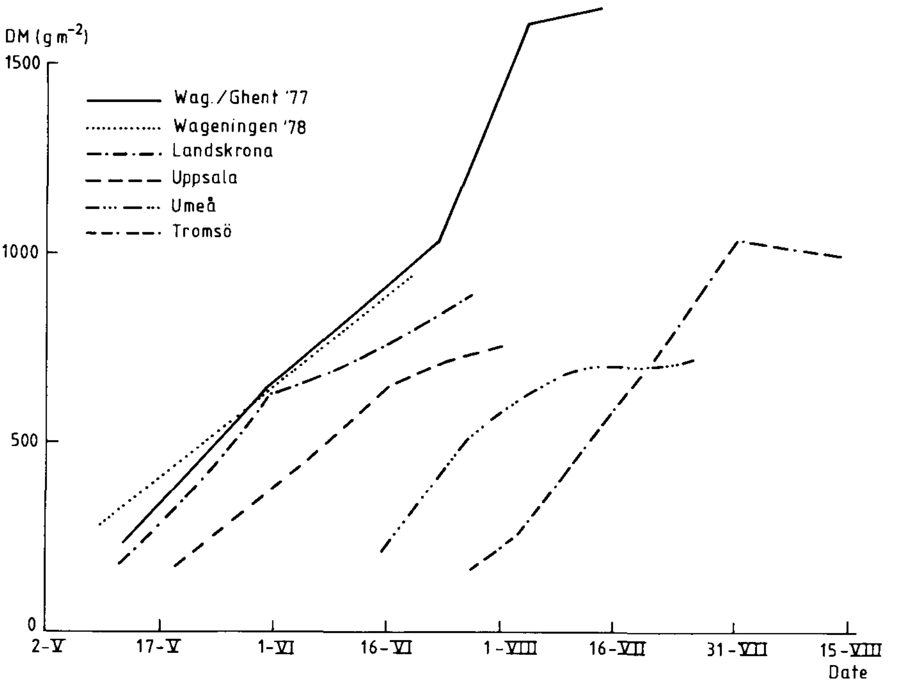

Fig. 1. Production curves of timothy at the different sites.

spring (Alberda & Sibma, 1968). The small area of 0.0625 m^2 and the limited number of samples taken on a sampling date did not permit firm conclusions. So yield data have to be considered with great care. However rate of production at Tromsö was higher, even where solar radiation and temperature were low. Maybe the long day and the need for completion of the reproductive cycle in a very short time accelerated rate of production considerably. Almost as high a rate was reached in other trials at Tromsö (Østgård, 1962). Final yield at Ghent seemed extremely high, up to 1600 g m^{-2}, which has never been reached in grass in a single cut. This may be due to sampling errors. Fig. 1 shows the production curves at the various sites.

Standard errors in morphological and chemical composition will be smaller than those in yield as they depend less on sample size.

Morphological development

Fig. 2 presents the proportion of leaf against age. It decreased rapidly at all sites as expected, in the initial stages of growth. Later the decline was smaller. Ears emerged at all sites when proportion of leaf was about 50 %.

Chemical composition

Table 4 also presents the average chemical composition of the herbage at the sites. Nitrogen content was highest at Landskrona and lowest at Tromsö, perhaps because of differences in nitrogen supply from the soil. Differences in average content of wsc were only partly correlated with nitrogen content, presumably because solar radiation, temperature and reproductive development may have interfered.

Average content of cwc tended to be higher at higher latitude, whereas digestibility tended to be lower. The very high content of cwc and the low D_{om} of Wageningen/Ghent are certainly caused by the few samples at early age and the greater number of samples at late stages of growth.

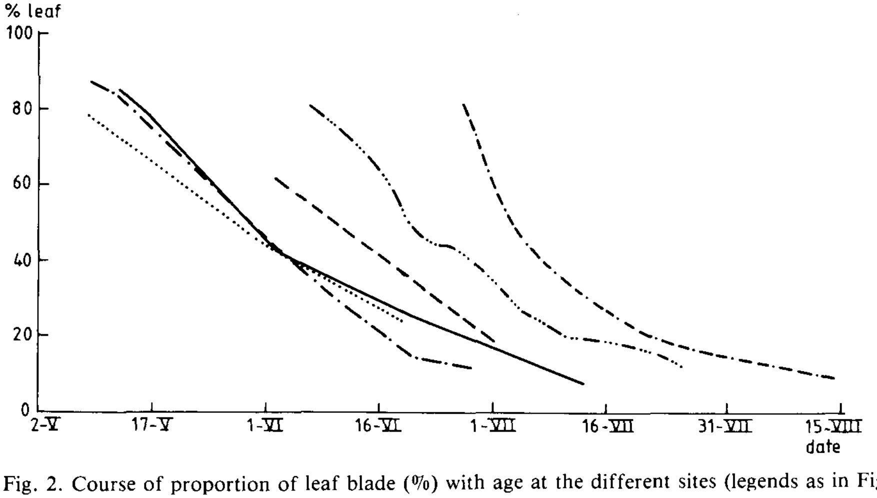

Fig. 2. Course of proportion of leaf blade (%) with age at the different sites (legends as in Fig. 1).

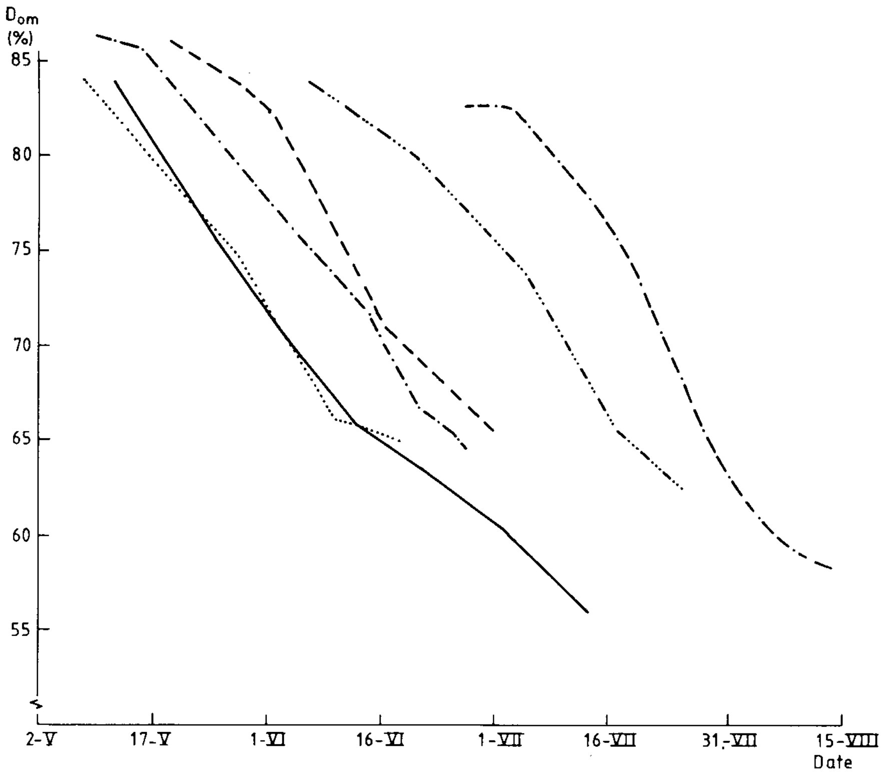

Fig. 3. Course of apparent digestibility of organic matter (%) with age at the different sites (legends as in Fig. 1).

Dynamics of digestibility of organic matter

Digestibility of organic matter along with content of crude protein are quality criteria of roughage for ruminants. Fig. 3 presents apparent digestibility of organic matter against age at the different sites. It shows that digestibility always declined as expected. This decline was rather linear at most sites except at the very beginning, and in the very end, when rates of grass production were small.

Average decline of digestibility with age in percentage units per day at the different latitudes is presented in Table 5 during the linear phase. For the whole crop (leaf + stem + dead) it was greater at higher latitude, as in the published data (Table 1).

As digestibility of the crop may be considered the result of digestibility of leaf, leaf sheath + stem and dead material, corrected for their contribution to the yield of organic matter, these dynamics in whole crop digestibility originate from the dynamics of digestibility of the various tissues. Leaf digestibility tended to decline somewhat slower at high latitude, perhaps because of the lower temperature (Table 5). However stem digestibility declined more rapidly at higher latitude, because of

Table 5. Average rate of decline in digestibility (D_{om}) during the rectilinear phase and digestibility for 50 and 70 % leaf sheath + stem.

Site	Rate of decline (% d^{-1})			Digestibility (%) for the content of leaf sheath + stem	
	leaf	leaf sheath + stem	total	50 %	70 %
Wageningen/Ghent 1977	0.19	0.52	0.45	75.0	59.0
Wageningen 1978	0.22	0.55	0.46	75.5	59.0
Landskrona	0.19	0.54	0.47	78.2	65.8
Uppsala	0.14	0.53	0.48	77.5	68.8
Umeå	0.18	0.70	0.58	80.5	68.8
Tromsö	0.12	0.64	0.65	83.0	76.0

the faster reproductive development in the shorter season of higher-latitude regions. This faster development is also reported by Harkess & Alexander (1969) and by Hu-okuma (1978).

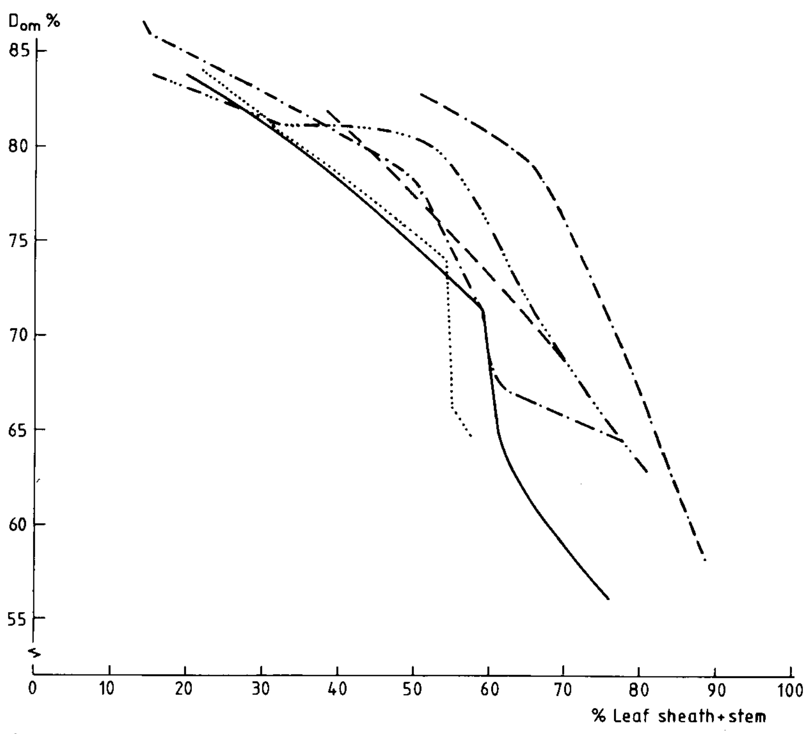

Fig. 4. Course of apparent digestibility of organic matter (%) with proportion of leaf sheath + stem (%) at the different sites (legends as in Fig. 1).

Digestibility and reproductive development

The present results suggest that digestibility declined faster at higher latitude together with the faster reproductive development. So the question arises whether digestibility and reproduction are related. By taking percentage of leaf sheath + stem as and indicator of reproductive development, we found (Fig. 4) that the lines did not cover each other. With the same percentage of leaf sheath + stem, digestibility (D_{om}) of the whole crop was higher at higher latitude. For instance, at Wageningen digestibility was 75 % with 40 % of leaf sheath + stem, whereas the same digestibility was found at Tromsö with 70 % of leaf sheath + stem. So digestibility in Scandinavia is much higher than in the low countries at the same morphological stage (Table 5).

There is thus a paradox that though ageing is faster in Scandinavia than in the low countries, digestibility is better in Scandinavia at the same morphological stage. This must certainly be ascribed to the very rapid reproduction at higher latitude. These aspects of D_{om} were also found in D_{cwc}, which is usually rather well correlated with lignin content of cell walls. At the same morphological stage, lignin content of the herbage would be lower at higher latitude. Perhaps lignification cannot keep pace with the very rapid stem development of the grasses in these cooler regions. These results and suggestions are in good agreement with those of Harkess & Alexander (1969) who found that digestibility of young timothy and other grasses were higher in Scotland than in the south of England, that the decline with age was greater in Scotland but that digestibility was better at the same morphological stage.

Leaf production too tended to be lower at higher latitude. It amounted to about 300 g m^{-2} at Wageningen and Landskrona, 250 g m^{-2} at Uppsala, 200 g m^{-2} at Umeå and only 150 g m^{-2} at Tromsö. As reproductive development was faster at higher latitude, leaf production presumably was finished sooner. So the greater ageing at higher latitude is also caused by the smaller contribution of leaves.

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