The success story of grass and legume silage in Sweden

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Résumé

En Suède, les prairies temporaires et les cultures fourragères représentent 45% de la SAU. La période de croissance de l'herbe varie de 150 à 240 jours et la saison de pâturage dure entre 2 mois (au nord) et 4 mois (au sud), ce qui nécessite des stocks de fourrage importants pour le reste de l'année.

Dans les années 70, des travaux sur l'ensilage d'herbe ont souligné ses atouts par rapport au foin réalisé traditionnellement : l'ensilage assure un fourrage de meilleure valeur alimentaire car il permet de récolter l'herbe au bon stade et avec moins de pertes. A une période où les exploitations agricoles laitières continuaient à se restructurer, la technique de récolte par ensilage s'est rapidement diffusée grâce à une bonne couverture de cette filière par les techniciens de développement. Au cours de la décennie suivante, la production laitière s'est encore considérablement accrue grâce à l'utilisation des concentrés, associée à un accroissement de la part de betteraves dans les rations ; elle est passée de 5 900 kg lait/VL en 1980 à 8 300 kg lait/VL en 2008. Du fait de l'augmentation du prix des concentrés, on a constaté un certain retour à l'ensilage d'herbe dans les rations (ration type pour une vache haute productrice en 2008 : 10 kg MS d'ensilage + 16 kg concentré, composé de 45% de grain, 35% de pulpes de betterave et 20% de concentré protéique).

Dans les élevages à viande, souvent de plus petites dimensions, l'ensilage d'herbe s'est surtout développé grâce à l'ensilage mi-fané et enrubanné. Dans les années 90, bien qu'ils soient très attachés au foin, les éleveurs de chevaux, assez nombreux en Suède, ont eux aussi introduit le mi-fané dans les rations, suite à des résultats expérimentaux.

Les prairies ensilées sont essentiellement composées de fléole (en raison de sa pérennité grâce à une bonne résistance aux conditions hivernales), de fétuque des prés, de ray-grass d'Italie, avec une proportion assez constante de légumineuses (essentiellement du trèfle violet mais la luzerne se développe, quand le sol est filtrant). Un travail de sélection est nécessaire pour développer des espèces fourragères productives et pérennes adaptées aux conditions suédoises. Le ray-grass anglais résiste mal aux hivers froids sauf dans le sud du pays ; des perspectives paraissent envisageables en améliorant sa teneur en sucres solubles. De même, le lotier semble mieux résister aux hivers froids en raison de sa teneur en tanins, qui s'avère également intéressante pour améliorer la qualité des rations…

Diverses expérimentations sont également présentées pour améliorer la qualité du fourrage : passer à 3 coupes par an (au lieu de 2), introduire du trèfle blanc (plus persistant que le trèfle violet et plus productif quand on effectue 3 coupes/an).

In Sweden, short-term leys incorporated into arable crop rotations are the main forage crop, unlike the perennial forage swards further south in Europe. Short-term leys and green fodder crops are the most widely grown crop in Sweden (45% of arable land in 2010). Due to the increasing price of concentrate, having regionally produced high-quality fodder is becoming important. Perennial crops have a number of positive environmental effects in terms of nitrate leaching, nitrous gases, carbon sequestration, soil structure, crop rotation, etc.

1. Climate conditions for grass and legumes in Sweden

Growth and development are influenced by temperature and light (light intensity and day length). The combination of temperature, insolation and day length is unique in Scandinavia/Fennoscandia and neighbouring parts of Russia. Insolation is not a limiting factor for growth, since most crops are C_3-plants. The temperature conditions are favourable in Scandinavia despite its northerly position, with all the Nordic countries except southern Denmark being above 55°N. The three Nordic capitals Helsinki, Stockholm and Oslo are situated roughly at the same latitude as Anchorage, Alaska. Thanks to the Gulf Stream, especially influencing winter temperatures, the climate is temperate, with a combination of favourable summer temperatures and long days. Despite the relatively low sun height, total global insolation is high due to the long day length.

Given the short growing season (day and night mean temperature > 5°C), which ranges from 150 days in the far north to 240 days in southern coastal areas, the grazing season is short and conserved forage accounts for about 50 % of total dairy cow ration.

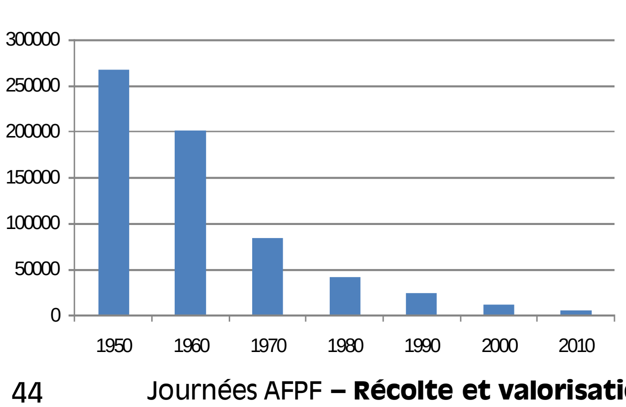
2. Feeding ruminants and horses until the 1960s

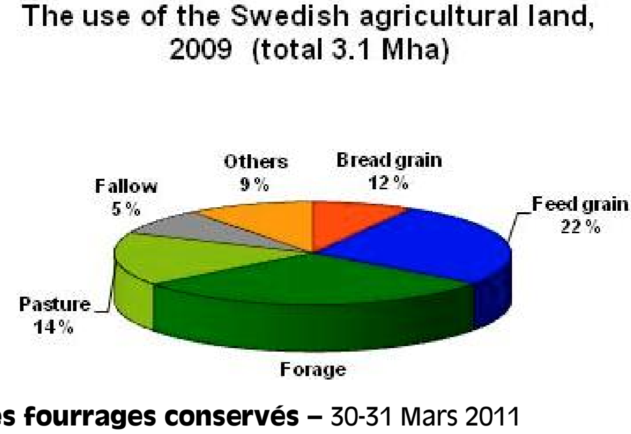
The grazing season in Sweden is May–October in the south and June–August in the north. Traditionally, grazing was allowed in areas not suitable for ploughing and cropping. Due to the accumulation of water and nutrients in the soil after 6–9 months of winter and the long daylight periods in the spring (17 h in the south and 22 h in the north on 1^{st} June), the growth rate of grassland is much faster in the early growing season. Therefore, in the past suitable grassland areas were excluded from grazing and used for production of hay for the coming winter. Hay was cut as a single cut in the end of June in the south and one month later in the north. The area was then used for grazing later on in the summer, when the decreasing growth rate required extended areas for grazing.

Hay making was a time-consuming process that included cutting, raking, filling the hay racks and finally transport to the hay barns. This produced a feed adequate for horses in moderate work or very low producing dairy cows. However, it always had to be complemented with some concentrate. Barley and oats were usually grown for this purpose. Field beans were sometimes used as a protein complement, but from World War II, imported protein sources such as coconut cake, groundnut cake, cottonseed cake and soybean meal became very common.

In the decades after World War II, the Swedish state invested great resources in rationalising agricultural production. The main goal was to decrease the need for labour on farms in order to release people to the fast growing industries. In the 1960s, this resulted in farm mechanisation and amalgamation, and the number of farms decreased. Figure 1 shows the result, a dramatic decrease from over 200 000 dairy farms in 1960 to less than 85 000 in 1970.

FIGURE 1 – Number of dairy farms 1950 to 2010 and use of agricultural land in Sweden 2009.





Total annual milk production remained about the same, 3 million tonnes, from 1960 to 2000. However, the drastic decrease in number of farms during the 1960s temporarily resulted in a lower total amount of milk produced, and motivated intense research during the 1970s to increase production, in order to secure of self-sufficiency of milk in the country. One of the main changes in cultivation during this time was that forage cultivation for winter feed moved from grazing areas to arable land with higher potential. This was necessary to keep winter feed production near the growing herd, and was possible because of increased crop yield brought about by mineral fertilisation.

3. Comparative studies of hay and silage in the 1970s

In the 1970s, great efforts were made at the Swedish University of Agricultural Sciences (SLU) to study the effects of conservation method and stage of silage/hay maturity when fed to dairy cows. Cuts at different developmental stages and silage with or without wilting were also studied (see e.g. BERTILSSON, 1983).

The studies concluded that silage gave more milk than hay. In one three-year experiment where 131 cows were given hay or silage in equal restricted amounts, the silage-fed cows produced 4–10 % more milk. When the harvest was postponed 10–20 days, the hay gave an 8–10 % decrease in milk yield, while the silage gave little decrease (Table 1).

The silage system displayed many other benefits in practice, e.g. it needed a shorter period of dry weather and resulted in lower field losses than haymaking. Since farm size had grown, the hay racks had been abolished in favour of field curing, which was easier to mechanise. However, when the dry hay was pressed in the field, a lot of the finer parts of the clover and grass plants were over-dried and became brittle and were lost, resulting in a lower energy and protein concentration in the hay, although it was cut on the same day as the corresponding silage. These field losses were accounted for in an experiment where the hay was harvested at 60 % DM and dried further by barn drying (Table 1). However, in practice the hay was dried to higher DM levels as often as the weather was good.

The studies at SLU made great impact on a dairy business that was declining and in great need of methods to increase production.

TABLE 1 – Daily feed data intake and animal performance data. Early cut at booting stage and late cut 10 days later. Three-year ley fertilised with 89 kg N, species timothy, meadow fescue and red clover. Hay wilted to 60 % in the field and to 87 % DM in barn drying. Silage direct-cut, 26 % DM. Forage fed restricted, concentrate according to milk yield. Lactation week 2–10, year 1 (from BERTILSSON, 1983).

	Early cut hay	Early cut silage	Late cut silage
Forage intake (kg DM day^{-1})	8.7^{a}	8.4^{b}	8.5^{b}
Concentrate intake (kg DM day^{-1})	8.1	8.4	8.6
Energy intake (MJ day^{-1})	197	199	194
Milk production (kg day^{-1})	26.1^{a}	27.4^{b}	26.2^{a}
Milk fat content (%)	4.56	4.65	4.57
Fat corrected milk (kg ECM day^{-1})	28.6^{a}	30.5^{b}	28.3^{a}

Means with different superscripts within rows are significantly different at $p < 0.05$.

4. Conversion from hay to silage for dairy cows in the 1980s

The research findings from the 1970s and early 1980s were taken into practical use through the advisory organisations, facilitated by the fact that the number of dairy farms was decreasing rapidly and that the farmers were members of various cooperative advisory organisations. About 90 % of dairy cows were in the milk recording system organised by the Swedish Dairy Association, which also organised artificial insemination. Cows were test-milked once a month, the data were collected in a national database and most farmers had the feed ration recalculated to each individual cow after each test milking, based on the latest yield and the feeds available at the farm. This system required feed analysis of the roughage produced on the farm. Thanks to this system, farmers became aware that a higher nutrient content in their home-grown forage immediately resulted in a ration that contained less commercial concentrate and that meant less cash outflow from the farm.

Experiments had shown that the silage system gave lower field losses and higher nutrient concentration in the forage than the hay system when harvested at the same time. However the difference was not so great as to be obvious in practice. However, the old tradition of harvesting the hay at a late stage of development gave the new system an advantage. When silage making was introduced, it was made clear that it had to be harvested in the grass booting stage and it soon became obvious to all that silage always had higher protein and energy content than hay.

5. Decrease in roughage in dairy cow diet in 1990s and increase in 2000s

In the early 1990s, the transition from hay to silage was almost complete in the dairy business. The production per cow increased with the shift to silage and in 1990 cows were producing 7 100 kg milk per cow per year, compared with 5 900 kg in 1980. After having achieved the positive response in milk production by changing to silage, the quest for higher production continued. The price ratio between concentrate and milk was such that it was profitable to increase concentrate to get more milk per cow. A summary of how high-producing cows were fed in Sweden from the mid-1970s until today gives an idea of how the feeding practice developed (Table 2). In the example, the shift to silage and higher forage quality was made between 1975 and 1982. Thereafter, the concentrate proportion increased steadily until some years into the new century. The reason why this was possible without negative consequences on animal health was the composition of the concentrates. The starch proportion was not allowed to increase to harmful levels and the cereals were successively replaced with fibre in the form of sugar beet pulp and other fibrous products. The amount of grain per cow remained at the same level from 1982 and 2008. The trend towards larger concentrate amounts was broken some years ago due to concentrate becoming too expensive in comparison to high quality forage. This is why silage is coming back in the dairy ration, even for the high-producing cows. Annual milk production per Swedish cow reached 8 300 kg in 2008.

TABLE 2 – Historical overview of feeding high-yielding dairy cows in practice in Sweden

1975	7 kg DM hay + 10 kg conc.	
1982	11 kg DM silage + 10 kg conc.	(75 % grain, 10 % beet fibre, 15 % prot. conc.)
1986	9 kg DM silage + 13 kg conc.	(60 % grain, 20 % beet fibre, 20 % prot. conc.)
1995	7 kg DM silage + 16 kg conc.	(50 % grain, 30 % beet fibre, 20 % prot. conc.)
2002	8 kg DM silage + 18 kg conc.	(45 % grain, 35 % beet fibre, 20 % prot. conc.)
2008	10 kg DM silage + 16 kg conc.	(45 % grain, 35 % beet fibre, 20 % prot. conc.)

6. Change to high DM, round bale silage converts smallholders

Although silage was introduced as the forage conservation system on all dairy farms in the 1990s, a large proportion of the grassland was still harvested as hay. That was predominantly on smaller farms with beef cattle and, of course, as winter feed for the growing horse population. Beef in Sweden is mainly a by-product from the dairy herd. Male calves go to beef production and since the replacement percentage in the dairy herds is high, a great deal of beef also originates from cull cows of varying age. However, some production of specialist beef cattle takes place on small or medium-sized farms. The winter feeding season for this type of animal is shorter, lowering the quantity of conserved feed needed. It is always difficult to feed silage from a silo to few animals, since the low speed of use can easily lead to problems with heating of the silage. Farms handling few animals also have a low level of mechanisation, and handling silage by hand is heavy work. However, turning to silage with higher nutrient concentration was attractive for beef farmers, who saw the possibility of raising the animals on forage only, without concentrate.

Farmers, always in the front line of development, tried their own way. Big round bale machines had become common to harvest and store straw among grain-producing farmers and were also used for hay in certain areas. The same farmers bought fertiliser in big plastic sacks. Some enterprising hay-producing farmers tried pressing wet grass instead of dry straw or hay in the bales, put them into the plastic sacks and tied them thoroughly – the round bale silage was invented!

The idea spread and the round bale system was soon for a subject for the research institutes. The initial finding from most studies was that round bales were not well suited for silage making. In relation to silos, the surface area is much larger and the air tends always to destroy the outer surface of all silage. Therefore, the expectation was for great losses in this system, and also a lot of problems with unwanted microbial activity such as enterobacteria, clostridia, yeast and mould. Such problems were found, but to a lower extent than expected and with great variability, which indicated that the system could be improved.

After some years with round bales in sacks, stretch film was introduced for wrapping and became a major success. The laborious work of putting the bales in sacks was removed, and the elastic layers of film worked as an ideal one-way valve, letting gases pass out of the bale but stopping air penetrating in. One of the major problems with the bales in sacks was that they blew up and were often punctured.

Trials soon reported good results with wrapped bales (LINGVALL & LINDBERG, 1989 ; LINGVALL *et al.*, 1990, 1993) and the system spread rapidly. A survey of silage systems in use in 17 European countries found that forage wagon and metered-chop systems were most common in almost all countries, but Luxemburg, Norway, Sweden, Switzerland, Italy and the UK reported that big balers were increasing (WILKINSON & STARKE, 1992). In Sweden, big balers were non-existent in the 1980 statistics, but were the 5th most sold in 1985 and the 2nd most sold in 1990.

7. Finally, horse owners turn to silage

By the late 1990s, the only major category of grass consumers that were still on hay were horses. The horse population in Sweden has increased substantially in recent decades, and horses consume a great deal of the forage produced. Ensiling the grass was reported to reduce voluntary intake in horses, and horse owners sometimes claimed that silage was refused by their horses. Since no real comparison had been made between hay and silage of the same crop, cut at the same time and in the same field, an experiment was set up in which silage with 35 % DM and haylage with 55 % DM or 70 % DM were compared with hay with 87 % DM (MÜLLER & UDÉN, 2007). When horses were presented with these feeds in a free choice system, silage was the first choice in 85 % of observations and had the highest consumption rate. Hay had the lowest consumption rate and was never completely eaten. The haylages fell in intermediate order with the drier least popular. The conclusion was clear; horses like silage and haylage better than hay.

Other experiments dealt with different additives and dry matter (DM) levels (MÜLLER, 2005). The silage was made using a conventional high-density hay baler that produced square bales with dimensions 80 cm x 48 cm x 36 cm. The idea was to produce silage that was easy to handle in horse stables and thus attractive to horse owners.

8. How did the new conditions influence seed selection ?

Forage species and varieties well adapted for different purposes and regions are crucial for high quality and quantity in forage production and thus beef/dairy farm profitability. The problem with introducing winter-hardy plant material from e.g. Canada into Sweden is that growth starts earlier in spring and stops later in autumn in Sweden than in Canada. It is necessary to breed and test plant material for Sweden, where SLU runs the official variety testing programme (VCU) (HALLING, 2008 ; RUTH, 2010). The plant material mainly consists of Swedish-bred varieties. Lantmännen SW Seed has active breeders of forage crops, e.g. timothy, meadow fescue, perennial ryegrass, cocksfoot, lucerne, red clover and white clover, but a great proportion of the forage seed sold comes from other countries validated for the EU list. Fortunately, most of these varieties are also validated for Swedish conditions.

Characteristics important in utilising inherent seasonal growing pattern, competitiveness, resistance to pests and winter hardiness of species/varieties include: role in cropping, grazing and feeding system; persistence; cutting and fertilising regimes.

In the past decade, the amount of sown legumes in Swedish short-term leys has increased from 16.3 % to 17.5 % of the total amount of certified and imported seed of the main forage species for silage production (Table 3) (Swedish Board of Agriculture, 2010). The ratio of different species has changed over time, with red clover having decreased and lucerne having increased. In recent years, there have been studies on fibre quality in timothy, leading to improved varieties and more sown timothy than before. However, there have also been some setbacks in the use of ryegrasses, as despite the nutritional advantages of these high-yielding grasses, the climate conditions in Sweden sometimes prevent efficient usage of these species. Accordingly, the most winter-hardy forage grass, timothy, has received new attention. Following successful breeding results in the recent years, the use of Festulolium and tall fescue has also increased. Tall fescue is a good example, where breeders recently have improved the quality in combination with existing good performance (HALLING, 2008).

TABLE 3 – Certified + imported seed of main silage crops in Sweden (10^3 kg year^{-1})**. Percentage forage legumes/forage legumes and grasses**

Species		2002/2003		2009/2010	
English name	Latin name	(10^3 kg)	(%)	(10^3 kg)	(%)
Red clover	*Trifolium pratense* (L.)	806.7	78	550.4	64
White clover	*Trifolium repens* (L.)	155.8	15	139.9	16
Alsike clover	*Trifolium hybridum* (L.)	13.8	1	31.5	4
Lucerne	*Medicago sativa* (L.)	60.0	6	127.5	15
Birdsfoot trefoil	*Lotus corniculatus* (L.)	4.2	0	6.7	1
Total forage legumes		**1 040.5**	**100**	**856**	**100**
Timothy	*Phleum pratense* (L.)	2 072.9	39	1 859.9	46
Meadow fescue	*Festuca pratensis* (Huds.)	1 567.9	29	722.9	18
Tall fescue	*Festuca arundinacea* (Schreber)	29.0	1	253.1	6
Perennial ryegrass*	*Lolium perenne* (L.)	1 513.5	28	1 022.3	25
Hybrid ryegrass	*Lolium x boucheanum* (Kunth)	40.5	1	-	-
Festulolium *ssp.*	*x Festulolium*	49.0	1	96.1	2
Cocksfoot	*Dactylis glomerata* (L.)	69.8	1	68.6	2
Total forage grasses		**5 342.6**	**100**	**4 022.9**	**100**
Legumes/(legumes + grasses)			16.3		17.5

* includes amenity varieties

To conclude, the main breeding targets for forage crops in Sweden are large yield, persistence (i.e. winter hardiness and pest resistance), high nutritive value e.g. concerning digestibility, crude protein and fibre quality, and satisfactory seed production.

9. More intensive harvesting regimes

Traditionally, cutting frequency has been restricted to two cuts a year in Sweden due to the short growing season. Several investigations have shown that production is greater but quality is lower with two cuts compared with three cuts a year in mixed swards with timothy, meadow fescue, and in some treatments red clover, a commonly used seed mixture (Table 4).

TABLE 4 – Dry matter yield (kg DM ha^{-1}) **and digestible energy** (MJ kg^{-1} DM) **in grass and mixed swards with two and three cuts a year**, resp. 100 kg N ha^{-1} supplied. (KORNHER, 1982**)**

	2 cuts		3 cuts	
Seed mixture	**Yield**	**Energy**	**Yield**	**Energy**
Timothy + meadow fescue	7 760	10.0	6 210	10.9
Timothy + meadow fescue + red clover	9 110	10.0	8 035	10.3

10. White clover also for silage

To improve the forage-based diets with required nutritional quality and quantity, the choice of species and of suitable management strategies is crucial. High digestibility, ensuring large forage intake, and slow decline with time are major advantages in legumes compared with grasses, especially when the weather is capricious. Traditionally, white clover has been grown for grazing in Sweden. However, in the 1980s, more erect varieties of white clover were introduced and studies were carried out to test the potential for inclusion of white clover in mixed, short-term leys.

An extensive study (15 field trials) was carried out with two different mixtures of white or red clover with timothy and meadow fescue, and smooth-stalked meadow fescue (*Poa pratensis* L.). Three nitrogen levels were included (0, 100 and 200 kg N ha^{-1}). The swards were cut three (silage or hay developmental stages) or four times a year for four consecutive years (SVANÄNG & FRANKOW-LINDBERG, 1994).

As a mean of different fertilising and cutting regimes, the white clover/grass mixtures (WC) were better than the red clover/grass (RC). The yield from WC with no fertiliser N supplied was about the same in the fourth year as in the first year (7 700 kg DM ha^{-1}) (Table 5). The corresponding yield in RC decreased from 8 400 to 5 500 kg DM ha^{-1}, resulting in an increasing amount of weeds. Irrespective of harvesting regime, root rot is the major obstacle to more long-lived RC swards. An early first cut and short defoliation intervals increased the WC content. Nitrogen fertilisation increased the DM yield, but decreased the clover percentage and the clover yield in the sward. Due to less competitiveness, WC content was more depressed than RC content when N was applied. The margin effect of N on DM yield was largest in the 0–100 kg N ha^{-1} interval (Table 6). It was larger in RC than in WC except in the first year with 100 kg N ha^{-1}. The introduction of white clover facilitated more flexible sward management, sometimes with harvesting and grazing in combination.

Most of the available forage seed mixtures contain both red and white clover. FRANKOW-LINDBERG *et al*. (2009) found that red clover as a single legume species or in a mixture was superior at a dry site, while multi-clover/grass species mixtures were superior at a wet site. Stability of clover yields can generally be increased by including both white and red clover in the seed mixture, but not total DM yield.

TABLE 5 – Effect of nitrogen application on DM yield in mixed swards fertilised with 0, 100 and 200 kg N ha^{-1}, respectively (kg DM ha^{-1}). Mean for *Trifolium* ssp. and harvesting systems.

N level	Trifolium ssp.	1st year	2nd year	3rd year	4th year
0 kg N	**Red clover**	8 430	7 647	6 363	5 491
	White clover	7 724	8 085	7 441	7 765
100 kg N	**Red clover**	9 597	9 359	7 795	7 141
	White clover	9 123	9 534	8 169	8 152
200 kg N	**Red clover**	10 409	10 202	8 569	8 213
	White clover	9 920	10 246	8 619	8 565

TABLE 6 – DM yield in mixed swards on the margin of nitrogen application in the intervals 0–100 kg N ha^{-1} and 100–200 kg N ha^{-1}, respectively (kg DM kg^{-1} N). Mean for *Trifolium* ssp. and harvesting systems.

N level	Trifolium ssp.	1st year	2nd year	3rd year	4th year
0-100 kg N	**Red clover**	11.8	17.4	14.5	13.0
	White clover	14.4	14.7	7.7	7.2
100-200 kg N	**Red clover**	8.3	8.7	8.2	10.1
	White clover	8.2	7.3	4.8	3.9

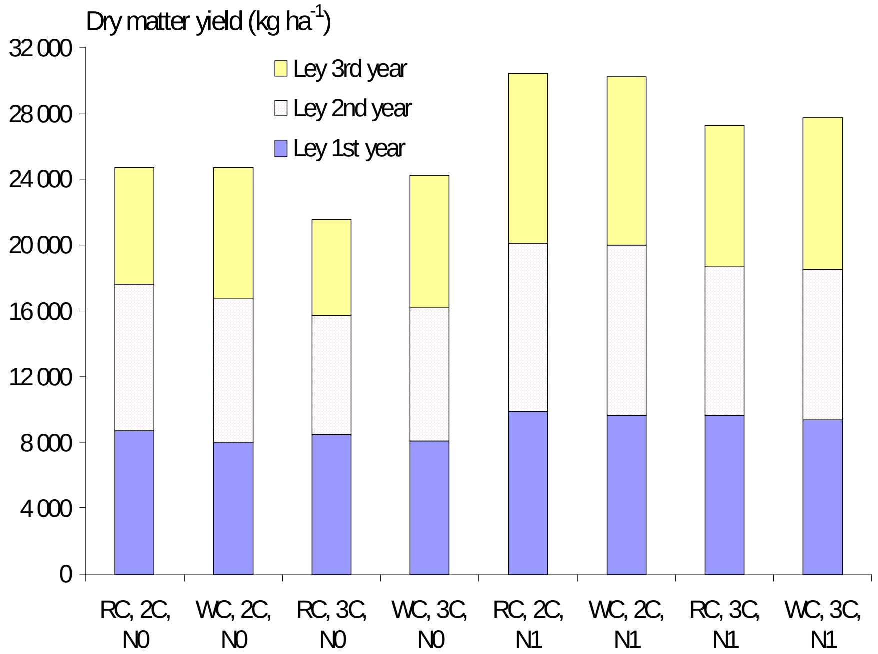
11. White clover for less intensive silage systems?

White clover is more persistent than red clover and higher yielding in intensively cut systems. The studies in the late 1980s led to a growing interest by Swedish farmers in using white clover as a silage crop. The question was whether white clover could be recommended in areas with less intense production systems due to farming tradition and climatic conditions.

In a study with 11 field experiments in southern and central Sweden, mixed swards containing red or white clover were cut two or three times a year for three years following establishment, and fertilised with 0 and 100 kg N ha^{-1}, respectively (NILSDOTTER-LINDE *et al*., 2002). The number of cuts significantly affected DM yield, but the response varied between sites and with sward age. The effect of N on DM yield was positive, on average, in both red and white clover/grass mixtures.

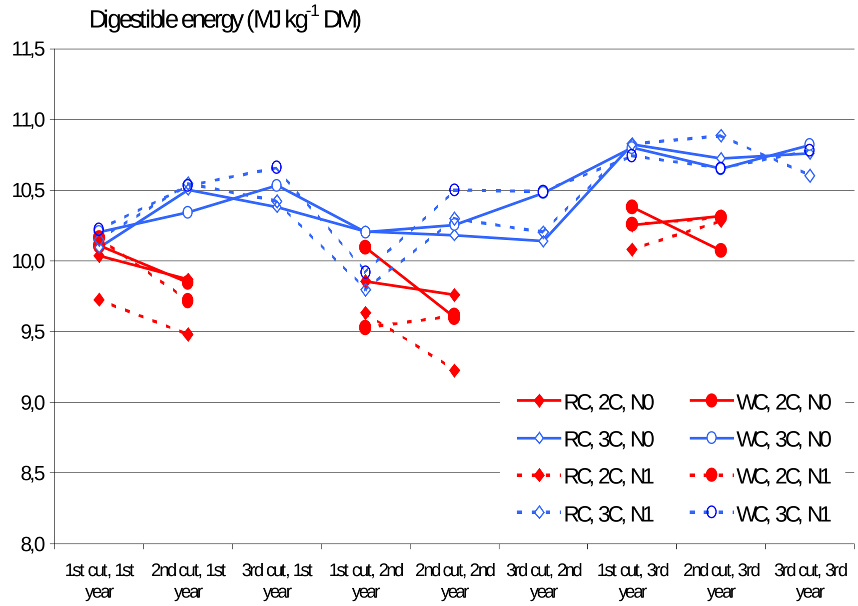
Nitrogen fertilisation rate significantly ($P < 0.001$) affected DM yield of individual cuts and total yield per year (Figure 2). The number of cuts also affected yield, with two cuts giving larger total yields than three, an effect that increased with sward age. On average, the difference between red and white clover yield was small, but in the third year unfertilised white clover yielded more than unfertilised red clover.

FIGURE 2 – Total dry matter yield (DM, kg ha^{-1}) **for combined treatments** (all cuts and years) **as an average of 11 field experiments.** RC = red clover, WC = white clover, 2C = two cuts year^{-1}, 3C = three cuts year^{-1}, N0 = 0 kg N ha^{-1}, N1 = 100 kg N ha^{-1}.



The number of cuts had the largest effect on the mean nutritional quality of the herbage, especially digestible energy (MJ kg^{-1} DM) (Figure 3), although at quite low levels in many cases (< 10.5 MJ kg^{-1} DM). Neutral detergent fibre was higher in N-fertilised treatments than with no fertiliser N, while crude protein was higher in treatments with three cuts and where the legume content was high. That was the case in plots with no fertiliser N supplied and where the white clover fraction increased, as occurred during the third year. In some cases, the content of crude protein was above 200 g kg^{-1} DM.

FIGURE 3 – Digestible energy (MJ kg^{-1} DM) **calculated from rumen soluble organic matter as an average of 9 field experiments in all treatments at each cut in years I–III**. RC = red clover, WC = white clover, 2C = two cuts year^{-1}, 3C = three cuts year^{-1}, N0 = 0 kg N ha^{-1}, N1 = 100 kg N ha^{-1}.



The conclusion was that total yields of white clover and red clover in mixed swards were similar in young swards and with two cuts per year. However, unfertilised white clover yielded more in the third year. The nutritional quality, especially digestible energy, was much better with three cuts than with two.

12. Lucerne for dry conditions

In the early 1980s, there was much field research on lucerne in Sweden, which was soon implemented by farmers in appropriate regions with a high soil pH. Soil inoculation with a suitable *Rhizobium* strain improves lucerne yield substantially (JÖNSSON, 1982). Following successful introduction, there were some setbacks owing to hard winter damage followed by very sparse swards. The winter buds just below the soil surface need oxygen and are susceptible to standing water and ice coverage. Field topography and drainage status are very important when including lucerne in leys. In recent years, there has been renewed interest in this crop for reasons such as the high fibre quality, the need for more home-grown protein in the rations and perhaps more pronounced dry periods in the summer.

13. Ryegrasses : possibilities and threats

With the arrival of intensive harvesting systems with more white clover included for silage, ryegrasses have become more interesting, even at Swedish latitudes. Large yield in combination with high quality is their major advantage. However, the reason why these species are not as prevalent in Scandinavia as further south is that their longevity is more or less restricted depending on climatic conditions, with winterkill always a threat. Perennial ryegrass is only recommended in the southern third of Sweden.

Swedish farmers have very good knowledge about management of domestic timothy, but are less knowledgeable about different treatments improving the overwintering capacity of ryegrasses. In nine field experiments with perennial ryegrass in the official testing programme in eastern and western parts of Sweden in the early 1990s, late autumn cutting was tested as tool to reduce damage caused by e.g. snow mould (*Fusarium nivale*) and thus improve winter survival (HALLING, 1994). Because of extremely mild winters with low occurrence of snow mould fungi in the study period, cutting as late as possible before cessation of growth significantly reduced the following spring yield by about 25 % in both the second and third year (Table 7). There was no residual effect of late autumn cutting on subsequent cuts.

TABLE 7 – Effect of autumn cutting management on subsequent DM yields in perennial ryegrass (10^3 kg DM ha^{-1}, mean different varieties)

Treatment	2nd year				3rd year
	1st cut	**2nd cut**	**3rd cut**	**Total yield**	**1st cut**
With late autumn cut	3.31	1.94	2.56	7.81	2.40
Without late autumn cut	4.46	1.92	2.71	9.11	3.25
Significance	**	NS	NS	*	**

Significance: NS $p > 0.05$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The growing interest in different ryegrasses and their hybrids is encouraging breeders and researchers to focus on better varieties and management strategies, and there are ongoing investigations on how cutting strategy influences overwintering capacity.

14. Forage species adapted for different purposes

There is increasing interest in species with special qualities, e.g. water-soluble carbohydrates and condensed tannins. For example, the perennial ryegrass cv. Aberdart, with high sugar content, is available on the Swedish market (HALLING, 2008). Studies on birdsfoot trefoil, a minor forage legume containing condensed tannins (CT), have confirmed that it can withstand Swedish climatic conditions. This led to an extensive trans-disciplinary investigation of its population ecology, protein efficiency and anti-parasitic effects in ruminants (NILSDOTTER-LINDE *et al.*, 2002), followed by a performance investigation in heifers (NILSDOTTER-LINDE *et al.*, 2004) and a corresponding investigation in dairy cows. A tendency for higher milk yield and somewhat higher milk protein concentration resulted in higher protein yield with a birdsfoot trefoil diet compared with a white clover diet. The most appropriate variety for Swedish conditions is cv. Oberhaunstaedter, which has shown good persistence and relatively high content of CT (1-2 g kg^{-1} DM).

Conclusion and future tasks

In Sweden, ruminants and horses rely on preserved forage as the grazing season is about four months in the south and only two months in the north. In the 1960s, hay making dominated completely, but over 20 years there was a dramatic change to silage making. Less dependency on good harvesting weather, better technical solutions and better animal response were the most important factors for this change. The large dairy herds were the first to change to grass and legume silage, stored in tower or bunker silos. When round bales arrived in the 1990s, smallholders too began making silage, while horse owners converted when small bales and haylage were introduced.

When silage replaced hay, the cropping system changed to more intensively managed, short-term leys. Two cuts were replaced by three in central and northern Sweden, and four or more in southern Sweden. Sward composition also changed, with white clover included for silage and with ryegrasses becoming more popular. However, ryegrass still has problems with winterkill, and remains a minority grass in Swedish leys. It is a challenge to find the right plant material combining persistence, large yield and high quality. Farmers have to formulate their own strategy regarding longevity, fertilisation, harvesting intensity and the purpose of production in choosing the right seed mixture.

There is currently renewed interest in producing home-grown protein to replace imported protein. Cultivation of legumes such as lucerne is therefore a future challenge in the area of producing dairy feeds. Other protein-rich crops such as peas and field beans harvested as whole crop silage are also attracting increased attention.

In the area of silage production, DM losses during silage making are gaining interest. It has been suggested that the magnitude of the DM losses differs significantly between the silo systems in use. Our own observations at the experimental farm at SLU indicate that the losses in tower silos and bunker silos are about 15–25 % while in round bale silos they are more in the region of 5 %. These figures indicate that the total acreage cultivated as forage could be decreased by about 10 % through appropriate management of silos and silage making processes.

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Fact sheet – silage making in Sweden :

Harvest

- **First cut 1June, second to fourth cut every six weeks if rainfall is adequate.**
- **Mower conditioner into windrows (Figure 4) or after spreading (Figure 5).**
- **Wilting to 25–35 % (bunker and tower silos) or 50 % (round bales).**
- **Self propeller chopper (Figure 6) or round baler (Figure 7).**
- **Bunker silo (Figure 8) or tower, bag or round bales (Figure 9).**

Figure 4.

Figure 5.

Figure 6.

Figure 7.

Figure 8.

Figure 9.