AARHUS UNIVERSITET

SOLID
Sustainable Organic and Low Input Dairying

Co-funded by the European Union

SOLID participatory research from Denmark: Use of herbs in pastures for dairy cows: Farmers' experience, pasture coverage analyses, and literature survey of Danish research results

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January 2015

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in collaboration with Thise Dairy Company

This work was undertaken as part of the SOLID Project (Agreement no. 266367 (http://www.solidairy.eu/), with financial support from the European Community under the 7th Framework Programme. The publication reflects the views of the author(s) and not those of the European Community, which is not to be held liable for any use that may be made of the information contained.

Summary

Semi-structured qualitative research interviews were conducted with eight organic dairy farmers (producers and shareholders of Thise Dairy Company), in which they shared their experience with growing herbs on grass fields on long-term basis for both grazing and silage production. Growing herbs implied some challenges: most herbs have a low competitiveness in relation to grasses and clover, their coverage is reduced rapidly from year to year as their survival during winters is low, and the seeds are quite expensive compared to grass seeds. Despite these challenges, the farmers continue to grow herbs year after year - constantly experimenting with optimizing the growing methods and seed mixtures. The motivations behind this were that they wanted to offer their animals a varied diet, they can see that the cows like the herbs, and sometimes even prefer them to grasses and clover, they believe in an increased mineral-uptake through the herbs, and that the herbs might have some medical effects on parasites. All in all, they trust that they are doing something good for their animals by offering them herbs in the feed.

Plant coverage analyses were done at seven farms, two of which had participated in previous projects having one 100% herb field each. The plant coverage analyses could be combined with the results of plant coverage analyses from the two previous years. The development of the two fields had turned out very differently: one had been spontaneously invaded by 6% wild herbs, 25% rough blue grass (poa trivialis) and 26% white clover (Trifolium repens), and ribwort plantain, red clover, caraway, lucerne and yarrow (sown). All other sown herbs had disappeared. The second pure herb field was now covered 50% by Lucerne, and besides this, caraway, red clover, ribwort plantain and very little chicory and salad burnet. In both fields, birdsfoot trefoil, yellow sweet clover, Sainfoin and starflower never established although the originally seed mixture had a quite high content of their seeds. The plant coverage analyses of the fields which were one to six years old, generally, dandelions, grasses and clover dominated and Lucerne became dominating. Among the herbs, only chicory and caraway was found after 5-6 years.

A literature survey was undertaken with focus on Danish studies, and 17 studies were in-depth reviewed with focus on pasture characteristics and qualities as well as milk composition, yield and content, and potential effects on animal health.

Photo on front cover from September 2013 of field, which is used for silage production, established in 2012, with very visible chicory and ribwort plantain.

Contents

1 Aims and research questions

The overall aim of this research was to give recommendations regarding the use of herbs in pastures under Danish climatic and farm conditions. To do this, we summarise and investigate current practical on-farm experiences and research results on the use of herbs in pastures for dairy cows through answering the following intermediary research questions:

- What motivates Danish organic dairy farmers to use herbs in their pastures for dairy cows, how do they use it, and which experiences do they have using it over a period of some years?
- How do herbs survive and establish in long term pastures used for grazing at organic dairy farms?
- What does Danish research on use of herbs in grass fields show regarding the characteristics of the pasture (e.g. mineral content), the establishment of herbs in the pasture, the effects on milk yield and milk quality as well as animal health?

2 Background

2.1 Farmer background

Organic farmers have shown an increasing interest in growing herbs in their pastures because they potentially can have health benefits, positive influence on the milk and the milk yield, and contribute to the variety and 'naturalness' of the pasture, among others by offering the cows a variety of different tastes and additional micro minerals and other substances. A few farmers have had herbs in their fields during many years, and have obtained long term experiences, while other farmers hesitate because they have heard about some of the challenges related to growing herb (Smidt & Brimer, 2005). Some of these challenges concern competition with other plants, surviving drought and winters and ensiling/harvesting methods.

2.2 Research background

At a workshop for Danish organic dairy farmers which took place in June 2012 as a part of the SOLID-project, several farmers discussed the need for collecting long term experiences with using herbs on pastures. There was especially focus on the survival of herbs in long-term pastures because it was a wish to prolong the number of years between ploughing with the aim of reducing CO2 emission (related to machinery) and building up carbon deposition in the soil. Obviously, it is not an option to investigate 'long term effects' of the use of herbs in a short research project, but the Danish SOLID partners, Aarhus University and Thise Dairy Company, decided that the SOLID project offered the possibility to contribute to a valuable knowledge sharing between the farmers through interviews with those who had long-term-experiences they wished to share. In addition, research has been conducted in Denmark during many years regarding the use of herbs in grass fields, and this research could be summarised and feed into the process of finding recommendations and directions for the future regarding the use of herbs in pasture.

3 Method of data collection

3.1 Location of the farm(s) and time of study

An invitation was sent to all dairy farmers (75) delivering milk to the private organic dairy "Thise". Anybody who would like to share their experiences with growing herbs in grazing systems or for hay or silage production were asked to contact us. Eight farmers responded and they were all interviewed during October 2013. Seven farmers were visited and interviewed at their home and the interview was supplemented with a plant cover analysis of relevant fields to describe the actual distribution of herbs in the fields, and one farmer was interviewed over phone. The interviews were semi-structured; they were based on an interview guide and were subsequently analyzed. The farmer interviews and plant coverage analysis were conducted in September-October 2013, and the literature survey took place in February-April 2014.

3.2 Plant coverage analysis on seven farms

The plant coverage analyses were conducted to know more details on the state of the grass-fields of interviewed farmers, and to identify potential patterns related to species, survival and development of the botanical composition of the crop. The botanical composition of herbs, grasses and legumes in relevant fields were analysed visually by describing how may % of the ground each species covered in a square of 0.5 m2. Such a square was analysed in each of at least two randomly chosen sites for every hectare of the field. The size of the smallest fields was 2 Ha. In small or more heterogeneous fields, one to two additional sites were analysed for every hectare.

3.3 Literature survey on the use of herbs from research primarily conducted at AU

Relevant publications were initially identified through systematic literature searches in the multidisciplinary database Web of Science, using a combination of keywords as shown in Table 1.

Table 1. Keywords for Database Search

Primary	Secondary	Tertiary
Herbs	Dairy	Grassland
Forbs	Cow	Yield
	Cattle	Milk
	Heifers	Ecosystem
		Environment
		Ecosystem services
		Animal health
		Health
		Forage
		Grazing
		Farming
		Biodiversity
		Sustainability
		Organic
		Pasture
		Mixtures

Overall, 1623 publications were identified based on these keywords. When only articles, conference proceedings and abstracts of European research and published after 2000 were considered, 61

articles were identified. Based on a quick survey of these articles, we decided that it was most relevant to focus on the Danish articles and conditions. Seventeen Danish studies were selected. They covered the following aspects regarding the use of herbs' effect on: 1) yield and forage quality, 2) milk yield and quality, 3) animal health, and 4) biodiversity and CO2 storage, in the dairy industry. Details from these articles are given in Annex 1.

4 Output/results

4.1 Interviews of 8 Danish organic dairy farmers

4.1.1 What motivated the farmers to start using herbs?

Half of the farmers started using herbs 14-18 years ago when they converted into organic production. As far as they remember their decision about using herbs was not influenced by advisors; they just wanted to offer their animals a more varied feed with different tastes. Some farmers had noticed that their cows preferred to eat trees and wild species of herbs if offered, rather than the grass which was available in the field in abundance. Other farmers emphasised that mineral supplementation was a reason because they perceive especially herbs with deep root systems like chicory to draw up minerals from deeper soil-layers. A third reason given by farmers was the expectations of medical effects of using herbs e.g. against parasites and against ruminant bloat/ tympanitis.

Milk producers of Thise dairy company have a long tradition for cooperating with Aarhus University in research projects. Four of the interviewed farmers started using herbs when they took part in such projects, while a fifth project-farmer had already used herbs for many years. One project had aimed at investigating the cow's mineral uptake from herbs, their preferences for different herb-species and the competitiveness of the herbs. It took place in 2006-2007 where 10 different herbs were sown broadcasted together with grass-seeds to establish a mixed herb-grass field (Søgaard et al., 2010). On one of the farms this field had not been ploughed since then, but there were only very few herbs left except clover. The other project focused on the effect of feeding with pure herb silage (without grasses) on the content of fatty acids in the milk, and on three farms a pure herb-field was established in 2011, and they still existed on two of the farms in 2013. All farms except one had used herbs in all pastures since they had been involved in the research projects. On farm not using herbs anymore the herbs were poorly established in the field, the crop was too open and the yield too low compared to the costs for seed. This farmer wanted to wait sowing herbs again in the field until more cost-effective methods would be developed.

4.1.2 Farmers make their own experiments with herb mixtures

The famers who started using herbs on own initiative 14-18 years ago have over years tried different compositions of herbs. One herb which has been used continuously is Chicory (Cichorium intybus). This herb normally establishes quit well in the field, the cows like it, it is believed to have a medical effect on parasites and on ruminant bloat and to have a high mineral content. Herbs like dill and parsley have been tried but given up again. Dill had a poor re-growth after harvest or grazing and parsley germinated very slowly, lost competition with other herbs, and never really established in the field. These very experienced herb-farmers continue to develop their methods and experiment with different mixtures. That is also the case for the two farmers who took part in the research projects by Karen Soegaard in 2007. In this specific project, seven different herb-species (chicory

(Cichorium intybus), ribwort plantain (Plantago lanceolata), caraway (Carum carvi), salad burnet (Sanguisorba minor), birdsfoot trefoil (Lotus corniculatus), chervil (Anthriscus cerefolium) and sainfoin (Onobrychis viciifolia) were sown. These two farmers both continued using herbs in all pastures, although just one (chicory) or a few species are used now.

4.1.3 Farmers use what is currently on the market

The herbs currently chosen by the farmers seem to reflect which herb-seed mixtures which are available on the market. Most farmers use these mixtures which include herbs like chicory, Sainfoin, ribwort plantain, caraway, dill (Anethum graveolens), birdsfoot trefoil and salad burnet. The farmers however know that some of the species often establish very poorly in their pastures, and if they had the possibility they would have adjusted the balance of herb species in the mixture. Some farmers add other herbs to these mixtures like alsike clover (Trifolium hybridum) while others choose just to add chicory seeds to the traditional grass-clover seed mixtures. The three fields with pure herb-culture which were established on three farms in 2011 during a research project by Petersen (2012 & 2013) with the aim of studying the content of fatty acids in milk when the cows were fed pure herb silage. The seeds sown on these fields were a mixture of 11% lucerne (Medicago sativa), 2% red clover (Trifolium pratense), 12% birdsfoot trefoil, 8% yellow sweet clover (Melilotus officinalis), 12% chicory, 24% salad burnet, 12% ribwort plantain, 12% caraway, 2% yarrow (Achillea millefolium) and 5% starflower (Borago officinalis). Lucerne is considered a herb in most trials, because it is not a part of a traditional grass mixture.

4.1.4 Farmers' experience that some herbs are better 'survivors' than others

Farmers had experiences with some herbs surviving better than others. Herbs like chicory, caraway, Lucerne, red clover and ribwort plantain are relatively large plants with deep roots and they both have a high competitiveness the year the pasture is established, and they are also the best survivors in a long term- perspective. Herbs like Lucerne and ribwort plantain seem better suited for cutting than for grazing and chicory and caraway seem to be the only plants able to survive grazing over several years. However, in general, farmers told that all sown herbs had difficulties surviving the winters, their occurrence were markedly reduced every year and barely existing after 3-4 years.

Farmers also experienced that in very dry periods, herbs coped better with drought than grass. Especially deep rooted herbs like chicory, lucerne and alsike clover had a remarkable drought resistance. Several farmers experimented with keeping their herb/grass pastures for more and more years before ploughing. The oldest pasture was 6 years old.

4.1.5 Sowing herbs broadly versus in stripes

Almost all interviewed farmers used herbs in all of their grass-fields, both fields used for grazing and for silage production. They either buy seed mixtures including herbs or they mix herb seeds with grass and clover seeds before sowing and in that way the herbs are broadcasted all over the fields. Only one farmer was sowing the herbs in 30 cm broad stripes for every 4th meter. He had observed that in this way the survival of the herbs was increased because the competitive pressure from grasses and clover was decreased. Most other farmers considered also to try herb-stripes in the pastures to increase the competitiveness. Some planned regular stripes all over the field while other farmers planned broad stripes at the edge of the field. To improve competitiveness and survival of the herbs, some of the interviewed farmers had added and increasing amount of herb seeds pr. ha.

4.1.6 Herb fields were not used for hay, but silage production worked well

The herb fields were normally never used for hay production because the dry leaves crumble away if they are handled more than once. Only one farmer had made hay one time on a field dominated by lucerne and in a period with stable sun and warm weather.

Silage production seems to work well except in one of the pure herb fields without grass. Here the leaves from chicory fall to the bare soil when cut, and when they dry they get sticky and difficult to pick up without soil. In this way the silage quality is markedly reduced due to soil contamination. In the other pure-herb field a cover of low grasses (poa annua) had established from the seed bank in the soil, and in this field there were no problems with soil contamination because the chicory leaves were carried up by the grass cover.

4.1.7 The cows enjoyed eating herbs

All farmers reported that their cows were happy to eat both fresh herbs when grazing (except the old tough stems of chicory) and silage made from herb-grass fields. Only the silage including sticky chicory and soil was disliked by the cows. Some farmers had the impression that especially in the springtime the cows preferred herbs and leaves from bushes and trees in hedgerows before grass. The farmer who established bands of herbs on the pasture described how the animals could stand in rows grazing primarily these stripes of herbs.

4.1.8 Farmers perceived herbs as contributing to good animal health

The farmers were asked whether they had noticed any effect from use of herbs on the health of their cows. Since there had not really been a before-after situation for many years, they were not able to see any difference. They all stated that they generally perceived their cows to be very healthy.

Cows which had taken part in the herb-silage project only got the pure herb-silage for 3-4 weeks, which was not enough to observe any difference on their health. Several farmers were convinced that the herbs contributed to the mineral supply of the cows. One interviewed farmer had not given other supplementary minerals to the cows the last six years – and had not experienced any negative effects. One farmer had many years ago a high prevalence of ruminant bloat in his herd. He solved that problem by exchanging red clover by alsike clover and adding caraway to the herb-seed mixture. In general the believed health-related effects on the cows and the fact that the cows seemed to enjoy the herbs were the main reason for the farmers to continue sowing herbs in the grass fields.

4.1.9 Seven of the eight interviewed farmers would use herbs in the future

Seven out of eight farmers stated that they planned to continue using herbs in their grass-fields, despite the facts that 1) herb seeds are quite expensive, 2) they do not have very obvious proves for the effect on the cows, and 3) growing herbs implies a lot of challenges in terms of survival of the herbs. All farmers constantly adjusted their way of growing herbs to improve the outcome. All farmers could mention one or more suggestions to further research, see box 1 below.

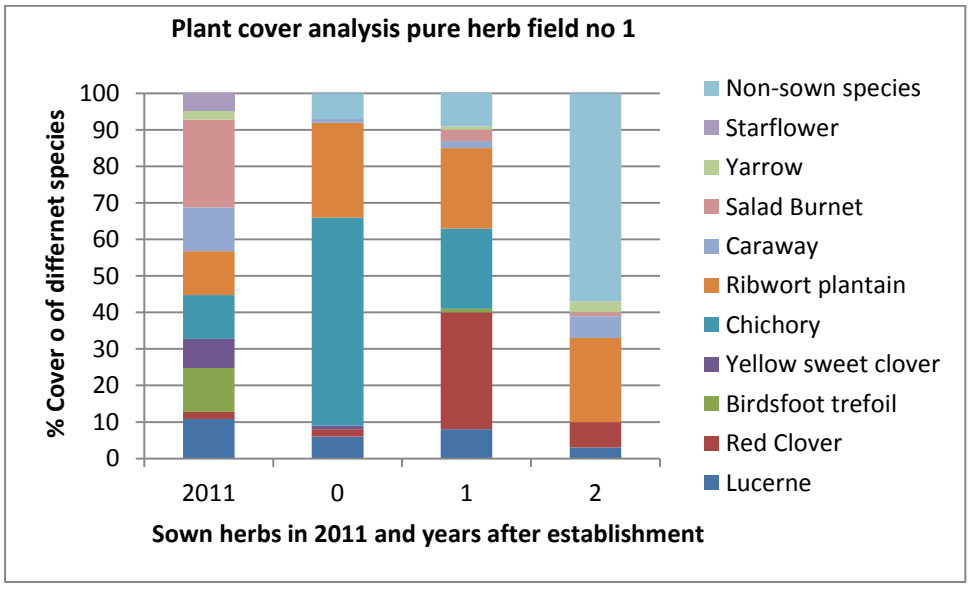
- The effect of feeding herbs on the health and reproduction of the cows
- Methane emission from feeding different herbs
- Developing growing methods improving the survival of herbs
- Development of herbs with higher competitiveness
- Herbs resistance to drought, heavy rain, frost etc.
- Effect of red clover on reproduction
- Development of other chicory types more suited for silage-production
- Development of seed-mixtures and growing systems suited for extensive production and heavy machinery
- Optimal time for sowing and cutting herbs
- Developing her mixtures with higher and more stable yields.
- Effect of chicory on gastro-intestinal helminth infections

Box 1. Farmer suggestions for relevant research on herbs in pastures for grazing and silage.

4.2 Plant coverage analysis

4.2.1 Research results from project at two Danish organic Thise farms

Of the three pure-herb fields which were a part of Petersens research project in 2011-2013 (Petersen 2012), one field was ploughed after two years, but the last two fields still existed on two of the visited farms. A plant coverage analysis was performed after the interview and compared to the plant cover analyses performed in 2011 and 2012 as a part of Petersens project. The figures below show that the development of the two fields turned out very differently. The field placed in the northern part of Jutland (no 1) had in 2013 been spontaneously invaded by 6% wild herbs, 25% rough blue grass (poa trivialis) and 26% white clover (Trifolium repens) probably originating from a seed-bank in the soil. Of the originally sown herb (column to the left) were the following species left: 23% ribwort plantain, 7% red clover, 6% caraway, 3% lucerne and 3% yarrow. The other sown herbs had disappeared.



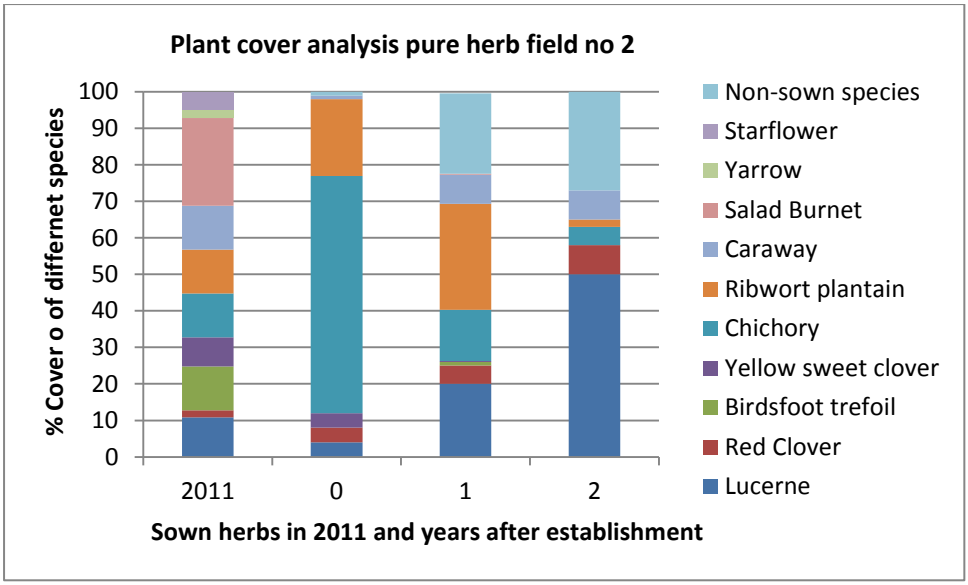
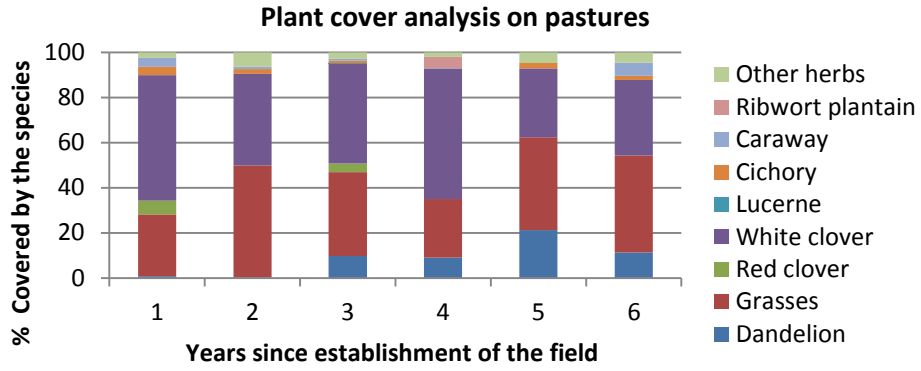


Figure 1 a & b. The results of 3 years plant coverage analyses of pure herb fields on two farms, of which the analysis done in the first two years was done in a research project by Petersen et al. (2012) and the analysis in last year was a part of this project. The left bar shows the original seed mixture.

The other pure herb field placed in the central part of Jutland was in 2013 very open (cut two weeks before the plant analysis was performed). It was covered 50% by the dominating lucerne and beside that a coverage of 5% caraway, 4% red clover, 2% ribwort plantain and <1% chicory and salad burnet. In both fields, birdsfoot trefoil, yellow sweet clover, Sainfoin and starflower never established although the originally seed mixture had a quite high content of their seeds. The bar "2011" at the left in the two figures below shows the original composition of the seed-mixture.

4.2.2 Plant coverage analysis done on seven farms, Sep.-Oct. 2013

On the seven farms that had still herb-grass-fields plant coverage analyses were performed on all relevant fields meaning one to six fields on each farm. The findings mostly confirmed the statements from the farmers, and it also confirmed findings in previous Danish studies. Grasses and white clover were dominating all over in different balances, and only ribwort plantain, chicory and especially caraway survived several years in the grass fields although more and more scarce. While the sown herbs diminished from year to year the wild herbs became more and more abundant – on pastures especially dandelion, different thistles and curly dock. On the fields used for silage production the grown herbs covered a much higher percentage and seemed to survive better. Especially in one field, lucerne was very dominating. The figures below show the average cover% of 10 pastures with an age of one to six years after establishment, and five fields used for silage production, with an age of one to two years after establishment. Only chicory and caraway were found in 5-6 year old pastures and only with a few specimens on each field.



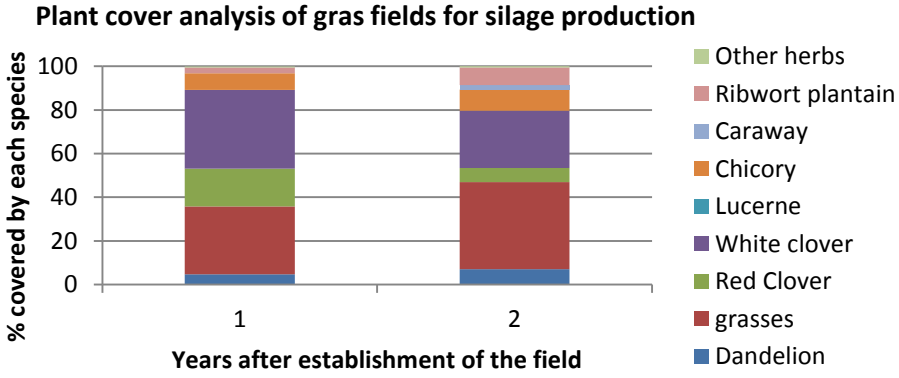


Figure 2 a & b. Results of plant coverage analyses on 10 fields at seven farms, at two-six fields per farm, over a six year period (Fig. 2a) for grazing and over a two year period (Fig. 2b) for silage production.

4.3 Literature study on the use of herbs in pastures in Danish studies

4.3.1 Effects of herb use on grassland yield

The effects of herb use on grassland yield were assessed in 13 of the included studies. Of those, four examined herb yield production in single stands (Elgersma *et al.*, 2012; Elgersma *et al.*, 2013b, 2013d, 2013c), 7 in mixtures of more than one herb (Eriksen *et al.*, 2012, 2013; Pirhofer-Walzl *et al.*, 2011; Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Søegaard *et al.*, 2013; Mortensen *et al.*, 2012) and 2 included both single stands and mixtures in its analysis (Mortensen *et al.*, 2013; Pirhofer-Walzl *et al.*, 2013).

4.3.1.1 Overall effect in yield

Elgersma *et al.* (2013b) compared the yield and herbage quality of different species taking account seasonal patterns across harvests in two years (2009 and 2010). Pure stands of five herb species: salad burnet (Sanguisorba minor), caraway (Carum carvi), chicory (Cichorium intybus), ribwort plantain (Plantago lanceolata) and chervil (Anthriscus cerefolium) and four leguminous: yellow sweet clover (Melilotus officinalis), lucerne (Medicago sativa), birdsfoot trefoil (Lotus corniculatus) and fenugreek (Trigonella foenum-graecum) were compared with a grass–white clover mixture in two annual harvest seasons. The average, annual herbage yield was highest in lucerne (15.4 t DM ha^{-1}), where chicory (10 t DM ha^{-1}), ribwort plantain (8.5 t DM ha^{-1}) and birdsfoot trefoil (9.5 t DM ha^{-1})

provided DM yield lower than the yield of perennial ryegrass–white clover mixture (12.5 t DM ha^{-1}). Performance of salad burnet, yellow sweet clover and caraway was much poorer averaging at approximately 5 t DM ha^{-1}). Chervil had poor growth after the first harvest (2009) and fenugreek did not survive the winter, and were therefore both disregarded from the analysis. Comparable results were shown in other studies (Elgersma *et al.*, 2012; Elgersma *et al.*, 2013d, 2013c) comparing all of the above species except chervil and fenugreek. Lucerne's high and comparable to the grass-white clover DM production was also reported by Pirhofer-Walzl et al. (2013) who included perennial grass and chicory in their comparisons. Perennial grass has the lowest yield in this study. Poor growth of chervil during the first harvest was observed also by Søegaard *et al.* (2012), though in comparisons solely between different mixtures.

Søegaard *et al.* (2012) investigated the beneficial properties for nutritive value and biodiversity of herbs in an organic setting using different grazing/cutting management for three mixtures: 1) ryegrass-white-/red clover 2) ryegrass-white-/red clover together with the herbs: chicory, plantain, caraway, birdsfoot trefoil, salad burnet, sainfoin, and chervil and 3) all the previous mixtures together with festulolium and lucerne. Results showed yield to be increased in mixture 3 compared to mixtures 1 and 2. Similar trends, though without statistical significance, were observed in more recent study by Søegaard *et al.* (2013) using the same mixtures and methodology. In contrast, Søegaard *et al.* (2008) did not observe yield to be affected by the mixture composition (the same as the two previous studies) but solely under cutting management practices.

In a study examining overall yield production across both pure stands and different mixtures Pirhofer-Walzl *et al.* (2013), compared pure perennial ryegrass, chicory, and lucerne stands with a mixture of white clover and perennial ryegrass and a mixture of white clover, perennial ryegrass, chicory and lucerne. A strategy of 4 cuts in two years was applied for all swards. Overall, pure stand lucerne and the mixture with the chicory and lucerne had on average the highest herbage yields; whereas yield from pure stand perennial ryegrass was on average approximately 73% lower. In general, chicory performed better than perennial ryegrass, but not as good as the swards with lucerne. Chicory's good yield performance was reported also by Mortensen *et al.* (2013). In this study pure stands of 11 species (red clover, salad burnet, field scabious, chicory, sainfoin, caraway, birdsfoot trefoil, dandelion, chive, yarrow, and ribwort plantain) were compared under both 1 and 4 annual cuttings with the standard mixture and a mixture of all 13 species included. Generally, the two mixtures showed somewhat higher yield compared to the pure stands, irrespectively of the cutting strategy. From the herbs in pure stands, besides chicory, the birdsfoot trefoil, plantain and field scabius seemed to perform better than the rest, but still not as good as the two mixtures.

4.3.1.2 Cutting vs. grazing

In the study of Søegaard *et al.* (2012) the management system strongly affected the proportion of herbs in the herbage of mixtures with highest proportion observed under cutting than grazing (29 vs. 18 % of DM). Similar and even more prominent differences between cutting and grazing of the same mixtures were observed in Søegaard *et al.* (2013). In both studies chicory, plantain and caraway were the plants showing the best competitiveness and the ones least affected by mix composition irrespectively of the management practice (i.e. grazing vs. cutting). Lucerne under cutting showed high proportion particularly in expense of the red clover, but it affected also the herbs, which is somewhat contradictive to Søegaard *et al.* (2008) who reported lucerne to suppress red clover but to not affect the herbs. In this latter study, birdsfoot trefoil and burnet were the two species least

affected by the management practice, whereas chicorys' increased by grazing and plantains proportion increased by cutting. In addition, in the most recent study (Søegaard *et al.*, 2013), yield from the grazing plots was reported to be higher compared to yield from cutting plots for all 3 mixtures.

4.3.1.3 Slurry application

The effect of different fertilization strategies on yield was examined in 7 of the included studies (Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Søegaard *et al.*, 2013; Pirhofer-Walzl *et al.*, 2011; Mortensen *et al.*, 2012; Eriksen *et al.*, 2012, 2013). Søegaard *et al.* (2013) examined the effect of 2 fertilizer levels (0 and 200 kg total N/ha in cattle slurry) on mixtures under cutting and grazing over a 4 year period. Results showed that fertilization with cattle slurry increased yields but reduced the proportion of legumes and of plantain. In contrast the proportion of chicory and caraway increased with slurry. Similar results for plantain, chicory and caraway were also reported by Søegaard *et al.* (2012), whereas fertilization by 200 kg total N/ha in cattle slurry was reported to increase the yield in all examined mixtures also in the earlier study of 2008 from the same research group (Søegaard *et al.*, 2008).

Mortensen *et al.* (2012) compared three mixtures of 100, 50 and 5% composition in herbs under two fertilization rates, (0 and 200 kg total N/ha in cattle slurry). Salad burnet (19.1%), fenugreek (19.1%), chicory (9.6%), caraway (9.6%), birdsfoot trefoil (9.6%), chervil (9.6%), plantain (4.8%), lucerne (9.6%), and melilot (9.6%) were included. For the mixtures with 5 and 50% herb content, perennial ryegrass and white clover were included for the remaining proportions. Overall, the authors observed a tendency to increased yield with fertilization across all mixtures. Application of slurry seemed to affect also the competitiveness of the herbs however none of the differences were significant. In an apparent follow-up of the same experiment, fertilization was reported to significantly increase yield in all mixtures (Eriksen *et al.*, 2012, 2013).

In 2011, Pirhofer-Walzl *et al.* (2011) published results from a 2-years experiment that investigated the effect of slurry application on yield and mineral composition across 4 cuts per year in a mixture comprising of 2 grass species (festulolium, perennial ryegrass), 5 forage legumes (white clover, red clover, lucerne, birdsfoot trefoil, sainfoin) and 5 herbs (chicory, plantain, caraway, salad burnet, chervil). Chervil and Sanfoin were not established and were not taken into account. Slurry application (200 kg total N/ha) resulted in higher yields when compared to unfertilized plots only in the initial cuts in both years. Slurry application was shown to initially (1st cut) suppress the proportion of legumes in both years. Though, the proportion of legumes increased from the first to the third cut both in fertilized and unfertilized plots. This was in expense to both grasses and herbs, except the second year in fertilized plots were herbs remained largely unaffected. In all cases, the contribution of birdsfoot trefoil and salad burnet in the mixture was small, whereas plantain and, to a lesser extent, chicory had the largest contribution to the proportion of herbs in the mixture.

4.3.1.4 Sowing rate, period and cutting frequency

The effect of different sowing rates and cutting frequencies or seasons on yield of pure stands or mixtures and on the botanical composition of the latter has been reported in 9 of the included studies (Elgersma *et al.*, 2013b; Eriksen *et al.*, 2012, 2013; Mortensen *et al.*, 2012; Mortensen *et al.*, 2013; Pirhofer-Walzl *et al.*, 2011; Pirhofer-Walzl *et al.*, 2013; Søegaard *et al.*, 2008; Søegaard *et al.*, 2013)

Mortensen *et al.* (2013) compared 11 herbs in pure stands with the standard mixture and a mixture of all 13 plants included across 2 different cutting frequencies (4 versus 1 autumn cut per season) showed that yield level depended strongly on both the specie and the cut frequency. Total DM yields of red clover, salad burnet, field scabious, sainfoin, caraway, dandelion, chive, ribwort plantain as well as of the standard mixture were significantly ($p<0.05$) higher under 4 than 1 cut per year. On the contrary, chicory, birdsfoot trefoil, yarrow and the 13 species mixture did not show significant differences in DM yield between the 2 cutting frequencies. Under a 4-cut per year management the authors did not observe significant differences in annual yield between the traditional standard mixture and red clover, field scabious, ribwort plantain and the 13 species mixture. The yields of the rest of herb species were significantly lower. More species were equally productive under the single autumn cut approach, but in this case the yields of salad burnet, sainfoin, caraway, dandelion and chive were reported rather low.

Several of the included studies examined whether there is an interaction effect on yield between increasing the proportion of herbs in the sword and the cutting frequency. Herb proportions in the sow of mixtures between 5 and 100% were compared in a 4 versus a 6 cut-strategy per growing season (Eriksen *et al.*, 2012, 2013; Mortensen *et al.*, 2012; Søegaard *et al.*, 2013). Results suggest that increasing the proportion of herbs in the sow results in increased DM yield under the 4-cut strategy and in decreased DM yield under the 6-cut strategy (Eriksen *et al.*, 2012, 2013; Søegaard *et al.*, 2013), and this is irrespective of fertilization (Mortensen *et al.*, 2012). Further, results from Mortensen *et al.* (2012), suggest the yield for the 100% herb mixture to significantly reduce over the years in the case of the 6-cut strategy, but not in the case of the 4-cut strategy. In this latter study a comparison between the proportion of lucerne (considered a herb in the study), caraway and chicory -the three dominant herb species in the case- demonstrated that the amount of chicory reduced through the years, whereas the amount of caraway increased. Lucernes performance was highest in intermediate year. Similar over time trends for caraways yield were reported by Søegaard *et al.* (2013), who observed yield of plantain to also decrease with time. Though, in contrast to the previous study, here chicory remained relatively stable. Overall the authors did not observe significant differences in the total proportion of herbs in the mixture with time, which in contrast seemed to depend more on the proportion of herbs in the seed mixture and the cut-strategy. Generally, they reported the proportion of herbs in the herbage to be similar to that in the seed mixture in the 4-cut strategy and significant lower, particularly for lucerne, in the 6-cut one (Søegaard *et al.*, 2013). Variations in the composition of the mixtures have also been reported in relation to the season. Søegaard *et al.* (2013) observed that the proportion of grass was high in spring and autumn and low in summer whereas caraway comprised up to 25% of herbage DM in the spring of the 3rd and the 4th years of the experiment. Grass proportion at spring (1st cut at May) was reported to be high also in the mixtures used by Pirhofer-Walzl *et al.* (2011). However, its proportion decreased from the first to the third cut in August, and a similar tendency was observed for the herbs included. On the contrary, the proportion of legumes was seen to increase between the first and the third cut. Patterns of contribution by individual species are rather complicated to interpret in this study as they seemed to depend also on the rate of fertilization and harvest year.

Decreasing trends in the proportion of grasses and herbs concurrently followed by an increase in the proportion of legumes between the 1st and the 3rd or even 4th cut were observed also in the study of Søegaard *et al.* (2008). In addition, in a study comparing the composition of mixtures between summer and winter the proportions of certain herbs (i.e. salad burnet, chicory and melilot) and grass

were higher in the spring than summer, whereas for lucerne and birdsfoot trefoil the opposite occurred (Mortensen *et al.*, 2012). In both the studies, the proportion of caraway in the mixture were least affected by the season/cut, and similar trends were seen for birdsfoot trefoil in the study of Søegaard *et al.* (2008) and for plantain in the study of Mortensen *et al.* (2012).

Pirhofer-Walzl *et al.* (2013) in their study comparing pure stands of chicory, lucerne, perennial ryegrass with the standard mixture and a mixture of all combined found that yields across communities were influenced differently by cuts and harvest year (i.e. there was a significant interaction between plant community, year of harvest and cut sequence). Generally, in all plant communities herbage yield seemed to decrease from the 1st to the 4th cut in both production years, with the exception of the 2nd cut in the 2nd year. Botanical composition of the two mixtures tested showed similar patterns of change by cut through the years. For both mixtures the proportion of grass decreased from the 1st to the 4th cut. On the contrary, the proportion of Lucerne on the all species mixture increased almost linearly through the cuts, whereas chicory remained relatively stable.

Differences in yield between harvest were also reported in the study with pure stands of Elgersma *et al.* (2013b). Growth patterns were very different between years with highest yield produced by the 1st cut in the 1st year and the 2nd cut in the 2nd year. In this study, for most species, the yield of the first cut was much higher in the 1st year compared to the 2nd year.

4.3.1.5 v) Competitors

Several studies have reported chervil,(Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Eriksen *et al.*, 2012, 2013; Pirhofer-Walzl *et al.*, 2011) sainfoin (Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Pirhofer-Walzl *et al.*, 2011), fenugreek (Eriksen *et al.*, 2012, 2013; Mortensen *et al.*, 2012) and melilot (Eriksen *et al.*, 2012, 2013; Søegaard *et al.*, 2013) to be weak competitors that in most cases were outcompeted from the beginning and did not establish at all. Birdsfoot trefoil, dandelion and salad burnet were also reported to have low competiveness in mixtures (Søegaard *et al.*, 2013; Søegaard *et al.*, 2012). From herbs chicory, plantain and caraway showed the greatest competiveness when applied in mixtures (Pirhofer-Walzl *et al.*, 2011; Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Søegaard *et al.*, 2013; Mortensen *et al.*, 2012). Lucerne was consistently reported a very competitive specie in mixtures (Søegaard *et al.*, 2012; Søegaard *et al.*, 2013; Mortensen *et al.*, 2012). This was mainly in expense of red but also white clover (Søegaard *et al.*, 2013; Søegaard *et al.*, 2012).

Concerning the competiveness against unsown species Søegaard *et al.* (2008) showed that mixtures of 10 and 13 species of grasses, legumes and herbs had better performance compared with the standard mixture of perennial ryegrass, white clover and red clover. When compared with pure stands the standard and the same 13 species mixtures were reported to have strong competiveness against unsown species, but comparable performance was also reported for chicory, caraway, red clover and ribwort plantain in the pure stands (Mortensen *et al.*, 2013). In another study, Søegaard *et al.* (2013) compared different mixtures of dandelion with either birdsfoot trefoil, lucerne, or red clover with mixtures of salad brunet with the same legumes. The authors reported the proportion of unsown species to be highest (from 9% in the beginning to 75% at the end) in the mix of birdsfoot trefoil and salad burnet and lowest in the mixture of red clover and dandelion (2 to 4%), which then showed the highest ability to keep down unsown species (which could also be perceived as 'weed'; see later discussion on 'herbs' versus 'weed').

Management practices such as cutting vs. grazing, frequency of cutting and fertilization as well as the harvest year have also been shown to affect botanical composition of mixtures (Mortensen *et al.*, 2012; Søegaard *et al.*, 2012; Søegaard *et al.*, 2013; Eriksen *et al.*, 2012, 2013; Pirhofer-Walzl *et al.*, 2011; Pirhofer-Walzl *et al.*, 2013; Søegaard *et al.*, 2008). Detailed descriptions of these findings can be found on previous sections.

4.3.2 Herbage quality

Herbage quality as measured by fibre composition and in vitro organic matter digestibility (IVOMD). Digestibility was investigated in 6 studies (Elgersma *et al.*, 2013b, 2013c; Larsen *et al.*, 2012; Petersen *et al.*, 2011; Søegaard *et al.*, 2008; Søegaard *et al.*, 2012), whereas vitamin content in herbage was reported in 6 (Elgersma *et al.*, 2012; Elgersma *et al.*, 2013a; Elgersma *et al.*, 2013d, 2013c; Larsen *et al.*, 2012; Petersen *et al.*, 2011), and fatty acid content in herbage was reported in 3 studies (Petersen *et al.*, 2011; Elgersma *et al.*, 2013a; Larsen *et al.*, 2012). Phytoestogens and mineral (macro and micro) concentrations were included in the studies of Andersen *et al.* (2009) and Pirhofer-Walzl *et al.* (2011), respectively.

4.3.2.1 Digestibility, fibre and crude protein content

Elgersma *et al.* (2013b), assessed forage quality of 4 herbs and 3 leguminous forbs cultivated in pure stands compared to a perennial ryegrass–white clover mixture. Neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), crude protein (CP) contents and in vitro organic matter digestibility (IVOMD) were measured. Findings suggested significant differences between species in all the above parameters. There were no overall patterns observed between functional groups (i.e. legumes vs. herbs). The highest NDF, ADF and ADL values were observed in plantain and Lucerne. The ADF and ADL levels in salad burnet, caraway and chicory were comparable and similar also to the levels of the standard mixture; but their NDF concentration was considerably lower both than in plantain and lucerne as well as in the mixture. Higher NDF concentration in Lucerne compared to chicory was also reported by Larsen *et al.* (2012). Birdsfoot trefoil had NDF and ADF concentrations that did not significantly differ from salad burnet, caraway and chicory, but its ADL concentrations were much higher. For all species fibre content differed significantly between harvests and for ADL also between years (highest in 2nd year). Concentrations of NDF, ADF and ADL were lowest in the 4th harvest. Comparisons of the fibre contents across the same species in the study of Elgersma *et al.* (2013c) resulted in similar observations in relation to individual species. No patterns across seasons or years were reported in this study.

Results demonstrating higher fibre concentrations in Lucerne and plantain compared to other herbs and legumes were reported also by studies comparing mixtures(Søegaard *et al.*, 2008; Søegaard *et al.*, 2012). Quality analysis per specie in these studies followed manual separation of the samples. As with the study of Elgersma *et al.* (2013b) birdsfoot trefoil was characterized as having high ADF levels concurrently with low NDF levels also in these studies, and chicory here was reported to have approximately the same nutrient value as red clover. When comparing the mixtures, NDF and ADL levels were lowest in mixture 1 (ryegrass, white clover, and red clover) compared to the mixture 2 (i.e. mixture 1 + herbs) and mixture 3 (i.e. mixture 2 + festulolium and Lucerne). Mixture 1 had also the highest IVOMD value and the lowest CP content and thereby the authors concluded that it was the mixture with the highest feeding value (Søegaard *et al.*, 2012). The comparison between mixture 2 and mixture 3 was not reported. In another study with mixtures, Petersen *et al.* (2011) determined and compared IVOMD, CP and ash levels of a multi-species herb mixture with those of

clover grass and traditional mixed ration. The herb mixture had lower CP and IVOMD levels than clover and TMR. Its ash content was also higher. TMR had the highest IVOMD and CP levels and the lowest ash content.

In individual species IVOMD levels were consistently shown to be low in non-clover legumes particularly lucerne and birdsfoot trefoil (Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Elgersma *et al.*, 2013b). In combination with this observation Elgersma *et al.* (2013b) in their study with pure stands reported legumes (Lucerne, birdsfoot trefoil, yellow sweet clover) and the standard mixture to share high CP levels compared with the herbs. Similar observations for CP in legumes were made also by Larsen *et al.* (2012), but this study did not report IVOMD levels between chicory, Lucerne and red clover to significantly differ. In contrast, chicory and especially caraway were shown to have higher IVOMD levels in comparison with legumes and other herbs in most of the studies addressing in vitro digestibility (Søegaard *et al.*, 2008; Søegaard *et al.*, 2012; Elgersma *et al.*, 2013b). Both species though were reported to have the highest level of ash (Elgersma *et al.*, 2013b, 2013c).

4.3.2.2 Vitamins

The vitamin content of pure stand cultivated herbs (salad burnet, caraway, chicory, plantain), legumes (yellow sweet clover, lucerne, birdsfoot trefoil) and standard mixture has been compared in a series of studies (Elgersma *et al.*, 2012; Elgersma *et al.*, 2013a; Elgersma *et al.*, 2013c, 2013d). Comparisons across harvest years, seasons and cuts were included. Overall, herb species gave higher α-tocopherol concentrations than legumes, except birdsfoot trefoil which did not significantly differ from both the herbs as well as the standard mixture. Among herbs, α-tocopherol concentrations were highest in birdsfoot trefoil followed by caraway and chicory. Concentrations of β-carotene were comparable between caraway, plantain and birdsfoot trefoil, and considerably lower and comparable between species in chicory, salad burnet, yellow sweet clover and Lucerne. Birdsfoot trefoil and the standard mixture had the highest lutein concentrations followed by caraway. Concentrations of lutein in the rest of the species were much lower and not statistically different between them. Fluctuations in vitamin concentrations both between seasons and cuts as well as across years were shown. Particularly, vitamin concentrations were shown to be lowest in the 2nd cut (early July) and highest in the 4^{th} cut (October) during both years of the experiment. However, for lutein differences in concentrations between years were shown to be statistically significant (Elgersma *et al.*, 2012; Elgersma *et al.*, 2013a). Interestingly, the authors reported chicory to contain considerable amounts of δ-tocopherol (19–67 mg kg^{-1} DM) that could not be detected in the other species. Concentrations of γ-tocopherol were highest in chervil (14 mg kg^{-1} DM) in comparison to the standard mixture (<2 mg kg^{-1} DM) and Lucerne (<4 mg kg^{-1} DM), which were the only other 2 species/functional groups that γ-tocopherol could be detected on.

In concordance with the studies of Elgersma *et al*., Lucerne was reported to have the highest concentrations of α-tocopherol when compared to chicory, red clover and white clover also in the study of Larsen *et al.* (2012). In contrast, concentrations of γ- and δ-tocopherol were reported to be significantly higher in chicory compared to the rest of the species. Concentrations of lutein and β-carotene did not significantly differ between chicory, Lucerne, and white clover and were highest in red clover. Chicory had higher violaxathin concentration that Lucerne and white clover. The authors did not observe significant differences between periods (May, June, August) for all the plants included.

Finally in a study comparing mixtures with the TMR, Petersen *et al.* (2011) found that the mixtures of herbs and clovers had higher vitamin value than TMR. The herb mixture had higher γ-tocopherol and β-carotene content than the clover mixture. With regard to the levels of α-tocopherol and lutein chicories concentrations were higher only in the beginning of August.

4.3.2.3 Fatty acids

Larsen *et al.* (2012) reported total fatty acid concentrations between white clover, red clover , chicory, and lucerne to significantly differ. The highest concentration was observed in red clover followed by chicory. Total fatty acid concentrations in Lucerne and white clover were lowest and did not significantly differ between them. In concern to concentrations of particular fatty acids, the authors reported chicory and Lucerne to have comparable concentrations of C18:0, C18:01*cis*-9, and C18:3n-3 that though were lower than red clovers. Chicory had higher levels of C16:0 and C18:2n-6 than Lucerne and for the latter also than red and white clover. The content of fatty acids was seen to decrease by period (from May to August), particularly in relation to C18:3n-3.

Elgersma *et al.* (2013a) examined the concentration of a series of 23 fatty acids in pure stands of herbs (n=4), legumes (n=3) and the standard mixture. Birdsfoot trefoil and caraway had the highest total fatty acids concentrations followed by salad burnet, the standard mixture, sweet clover and chicory and were lowest in plantain and Lucerne. Concentrations of C18:0 where highest in salad burnet and lowest in the other three herbs included (i.e. caraway, chicory, plantain). C18:1n-9 and C18:2n-6 levels were highest in caraway and comparable for the other species. In contrast to Larsen *et al.* (2012), concentrations of C18:0 and C18:3n-3 were somewhat higher in chicory than Lucerne, but C18:2n-6 levels in chicory were also higher while there were minimal differences in C18:1n-9 and C16:0 levels between these two species. C16:0 levels were lowest in plantain and salad burnet and about the same between the other species, and birdfoot trefoil levels were higher. C18:3n-3 levels were highest in the standard mixture and not statistically different between herbs as well as yellow sweet clover. Levels of C18:3n-3 in Lucerne was the lowest. Concentrations of n-3 and n-6 fatty acids followed the same patterns with C18:3n-3 and C18:2n-6, respectively. When looking on their ratio (n6:n3) this was highest in caraway and lower but not statistically significantly different between the most of other species. The authors observed significant differences in fatty acid concentrations with cut and for C16:0, C18:0, C18:1n-9 and C18:2n-6 also with the harvest year. Generally, fatty acid concentrations were lowest in the 2nd cut (July) and highest in the 4th cut (October).

In the study of Petersen *et al.* (2011) the highest concentrations of total, C18:1n-9, C18:2n-6, LCFA and MUFA were found in TMR compared to the mixtures of herbs and clovers who had similar levels for all the above. In contrast, there were no differences between the three mixtures when looking on the levels of CD18:3n-3.

4.3.2.4 Phyto-estrogens

Phytoestrogen content in herbage was studies in only one of the included studies (Andersen *et al.*, 2009). Four treatment diets for equal-sized groups of Danish Holstein cows were included; white clover, red clover, lucerne and chicory together with white clover. The total Phyto-oestrogen concentrations were reported to range from 237.5 to 21.399 mg/kg DM with the lowest level measured in chicory and the highest in red clover. The concentrations of Naringenin, Biochanin A, Formononetin, Glycitein did not significantly differ between white clover, Lucerne and chicory and they were general significantly lower than in the red clover. However, chrysin levels were not significantly higher in chicory compared to the other three herbage mixtures.

4.3.2.5 Macro and micro minerals

Pirhofer-Walzl *et al.* (2011) investigated in one study whether herbs, legumes and grasses differ in their macro- and micro-minerals concentrations. The macro-minerals tested were Ca, P, Mg, K, Na, N and S and the micro-minerals the Cu, Fe, Mn, Zn, Mo, Cr and B. Four cuts per year in two consecutive harvest years were performed. Five macro-minerals (P, Mg, K, Na, S) showed to be higher in herbs than grasses or legumes, independent of year and cut. In comparisons between the average levels of both years for the 1st and the 3rd cut, concentrations of P and K were highest in herbs and concentrations of N highest in legumes. Ca, Mg and S concentrations were higher in herbs than in grasses and legumes but only at the 3rd cut. Concerning micro-minerals, in general there were no clear differences between herbs and legumes but tendencies towards higher concentrations of B and Zn in herbs compared with the legumes and grasses were observed. Differences between cuts (1st vs. 3rd cut) were though evident. In particular, herbs and legumes had relatively high concentrations of Cu in both cuts whereas grasses only in the 2nd cut. For Fe and Mo, concentrations in grasses were higher in the 1st than the 3rd cut, whereas for legumes and herbs the opposite occurred. Herbs and grasses had greater Mn and Cr concentrations than legumes at the 3rd cut. In herbs and in grasses, the Mn and Zn concentrations increased from the 1st to the 3rd cut, whereas in legumes they remained the same or decreased. Concentrations of Zn, Cu and B were highest in the 3rd cut for all functional groups. Mineral concentration differences between the functional groups were not affected by slurry application as shown in ANOVA analysis.

4.3.3 Milk yield

Milk yield in relation to different types of herbs and/or mixtures was addressed in 3 of the included studies (Andersen *et al.*, 2009; Petersen *et al.*, 2011; Larsen *et al.*, 2012). No significant differences in milk yield by type of herb or compared to standard mixtures was observed in any of the above studies.

4.3.4 Milk quality

Andersen *et al.* (2009) examined phytoestrogen, fat and protein content in the milk of Holstein dairy cows using four treatment diets: white clover, red clover, lucerne, and white clover with chicory. All mixed together with perennial ryegrass. There was no overall effect of dietary treatment or period (May or June) on fat and protein content. When looking on phyto-oestrogens, lucerne and chicory did not show considerable differences in total or specific phyto-oestrogen concentration neither between them, nor when compared with white clover. However, milk from the red clover diet had 4 to 5.6 folds higher phyto-oestrogen concentration compared with the other 3 treatments. This was true both for the total phyto-oestrogen concentration as well as for the concentrations of equol, daidzein and formononetin. On the contrary, Enterolactone was 1.3 to 2 times lower for red clover compared with the other treatments. Treatment had no effect on the concentration of enterodiol.

Larsen *et al.* (2012) examined fatty acid, tocopherol and carotenoid content in the milk of 48 Holstein cows grazed in different mixtures of perennial ryegrass with either white clover red clover, chicory or lucerne. Fat and protein production and content were not affected by herbage type which is similar to what Andersen *et al.* (2009) have observed. However, urea content was significantly reduced for chicory (low protein content?) compared with the other three herbage types included. There was a significant interaction between herbage type and period (May to June) for urea content, due to a reduction from June to August for red clover compared with an increase for the other types of herbage. Concentration of α-tocopherol in the milk was highest in red clover and chicory. From the 10 fatty acids included in the analysis (i.e. C4; C6-C14; C11-C17; C16:0; C18:0; C18:1*trans*-11;

C18:1*cis*-9; C18:2n-6; C18:3n-3; and CLA*cis*-9,*trans*-11) differences between crops were observed for C18:0 which was lower in milk from cows grazing white and red clover, C18:2n-6 which was higher for cows grazing Chicory and for C18:3n-3 which was higher for white clover and comparable for the milk from cows from the other 3 crops. The level of C6–C14 was lowest in the milk fat from cows grazing Chicory and lucerne. Based on comparisons with previous studies from both Denmark and other EU countries (references: text in page 2895) the authors concluded that the production conditions that they practiced should be regarded as suitable for the production of milk high in C18:3n-3.

In a small study, Petersen *et al.* (2011) randomized 12 Holstein cows into 3 groups of 4 cows and examined the effect of diet on the milk fatty acid content. Three mixtures (1 per group) of feed were used: a) traditional total mixed ratio, b) a herb mixture of 43% chicory, 21% English plantain, 11% salad burnet, 6% birdsfoot trefoil, 6% white melilot, 3% caraway, 2% lucerne, 1% chervil and 7% unsown species, or 3) a mixture of white clover (78%) with perennial grass (21%) and 1% unsown species. In concordance with the 2 previous studies (Andersen *et al.*, 2009; Larsen *et al.*, 2012), diet did not seem to affect total fat content in milk. However, level of specific fatty acids differed as a function of diet. Specifically, the content of n-3 (sum of C18:3n−3, C20:3n−3, C22:5n−3 and C22:6n−3) and n-6 (sum of C18:2n−6, C18:3n−6, C20:3n−6, C20:4n−6 and C22:5n−6) was highest in milk from cows fed with the herb mixture, while the content of SCFA+MCFA (sum of C4:0, C6:0, C8:0, C10:0, C12:0) was highest in milk from cows fed with traditional total mixed ratio. Milk from the herb diet cows was richest in Retinol, but diet did not affect α-tocopherol and ß-carotene levels. Transfer efficiency from feed to milk was calculated as the amount of fatty acids secreted daily in the milk divided by the daily intake of fatty acids, and expressed as %. Transfer efficiency for n−3 and n−6 fatty acids was highest for cows fed with the herb mixture.

5 Conclusive remarks and recommendations

5.1 Conclusive remarks

- Danish farmers chose to have herbs in their pastures among others because of potential health benefits (e.g. parasite prevention and treatment), positive effects milk yield and composition, microminerals, being able to offer the animals a varied diet and a good taste, and ‘naturalness’ of the grass fields.
- Experienced challenges were competitiveness with other plants, drought and winters as well as ensiling/harvesting methods.
- Despite challenges, the interviewed farmers continued to grow herbs year after year - constantly experimenting with optimizing the growing methods and seed mixtures, based on the motivations mentioned above.
- Farmer observed that the cows liked the herbs, and sometimes even prefer them to grasses and clover.
- Plant coverage analyses on fields which had been sown with 100% herbs 5-6 years previously, showed very diverse results. Generally, dandelions, grasses and clover dominated, and lucern became dominating. Among herbs, only chicory and caraway were found after 5-6 years.
- Farmers’ experienced that some herbs generally never established, in particular birdsfoot trefoil, yellow sweet clover, Sainfoin and starflower. This is in accordance with the findings

by with Soegaard et al., 2011. While sown herbs rapidly disappeared over years, wild herb species like dandelion (Taraxacum officinale) and broadleaf plantain (plantago major) took over spontaneously and especially dandelion was dominating old pastures. Smaller plants like birdsfoot trefoil and salad burnet had large difficulties establishing even in fields with pure herb mixtures and no grazing. This leads to a conclusion that it might be a viable strategy for the future to explore more regarding 'natural herbs' – which often are spontaneously establishing themselves and will be robust and adjusted to the conditions – rather than trying to sow vulnerable herbs again and again.

5.2 Recommendations to farming practices

- Sowing herbs in stripes seem a viable strategy, making it relatively easy to re-establish in a long-term grass field.
- All (non-poisonous) herbs – also those which establish themselves and in some cases are considered 'weeds' – can potentially have some beneficial effects on the cows and their health and welfare, the milk, and / or the biodiversity on the field. This generally encourages many types of plants, grasses and plants in pasture, and discourages plain mono-cultural grass fields. It also points to a more explorative approach to develop strategies to keep more robust herbs, treasure those which naturally grows on fields, instead of focusing on expensive seed mixtures of herbs which have difficulties in competing on many pastures. For example, Birdsfoot trefoil, yellow sweet clover, Sainfoin and starflower were all identified as herbs which were difficult to grow.
- Silage making seems to be a better option than hay making based on herbs, under Danish and similar conditions.

5.3 Recommendations to further research efforts from interviewed Danish farmers

- The effect of feeding herbs on the health and reproduction of the cows
- Methane emission from feeding different herbs
- Developing growing methods improving the survival of herbs
- Development of herbs with higher competitiveness
- Herbs resistance to drought, heavy rain, frost etc.
- Effect of red clover on reproduction
- Development of other chicory types more suited for silage-production
- Development of seed-mixtures and growing systems suited for extensive production and heavy machinery
- Optimal time for sowing and cutting herbs
- Developing her mixtures with higher and more stable yields.
- Effect of chicory on gastro-intestinal helminth infections

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Caraway (Carum carvi)

Lucerne (Medicago sativa)

Salad burnet (Sanguisorba minor)

Ribwort plantain (Plantago lanceolata)

Chicory (*Cichorium intybus)*

Birdsfoot trefoil (Lotus corniculatus)

Sainfoin (Onobrychis viciifolia)

Starflower (Borago officinalis)

Yarrow (Achillea millefolium)