CHAPTER 10

Grass-legume Mixtures: A Valuable Resource for Grassland Based Milk Production

Beat Reidy and Peter Thomet

Grasslands are among the most important natural and managed land use systems in the world (Asner et al. 2004). In Europe, grassland covers about 30% of the agricultural area and forms the basis of an important part of the livestock sector. Roughage produced on semi-natural and sown grasslands has for a long time been the most important forage source for ruminants. With the intensification of ruminant farming, mainly during the second half of the last century, highly optimized rations based on maize silage and concentrates have become increasingly important. Nevertheless, roughage produced on semi-natural and sown grasslands is still a major source of forage for ruminants, especially in temperate regions where climatic conditions and topography limit the cultivation of arable forage crops such as maize and soybean. Although the perceived importance and prestige of grassland based milk production systems has waned, these systems may regain their attractiveness in the future when resources become scarcer (Spiertz and Ewert 2009). Support for grassland based milk production may also come from the perspective of human nutrition: several recent studies indicate that increased proportions of grass-based feed have strong and positive impacts on the nutritional and sensory qualities of milk (Couvreur et al. 2006; Colomb et al. 2008).

In certain regions of central Europe such as Switzerland, semi-natural and sown grasslands cover up to 70% of the total agricultural area due to the climatic and topographic constraints on arable farming (BFS 2011). Dairy production, therefore, relies to a large extent on grassland-based forage production, with roughage proportions of up to 90% in typical feed rations for dairy cows. Forage is primarily produced on semi-natural and sown grassland, with forages in crop rotations (leys) almost exclusively sown as grass-legume mixtures. Although productivity and species composition vary widely due to differences in regional climate and management intensity, grass-legume mixtures consist primarily of species from the families of *Lolium* (ryegrasses), *Festuca* (fescues), *Dactylis* (cocksfoot or orchardgrass) and *Trifolium* (clovers).

Milk production based on grass-legume mixtures

Grass-legume mixtures have a long tradition in Switzerland and are even today the major source of hay and green forage produced on cropland. Under the prevalent climatic conditions in Switzerland, with average annual temperatures ranging from 8–12°C (46–54°F) and annual rainfall from 800–1,200 mm (31–47 in), grass-legume mixtures in the central lowlands provide a major proportion of forage on mixed dairy farms. Grass-legume mixtures are generally

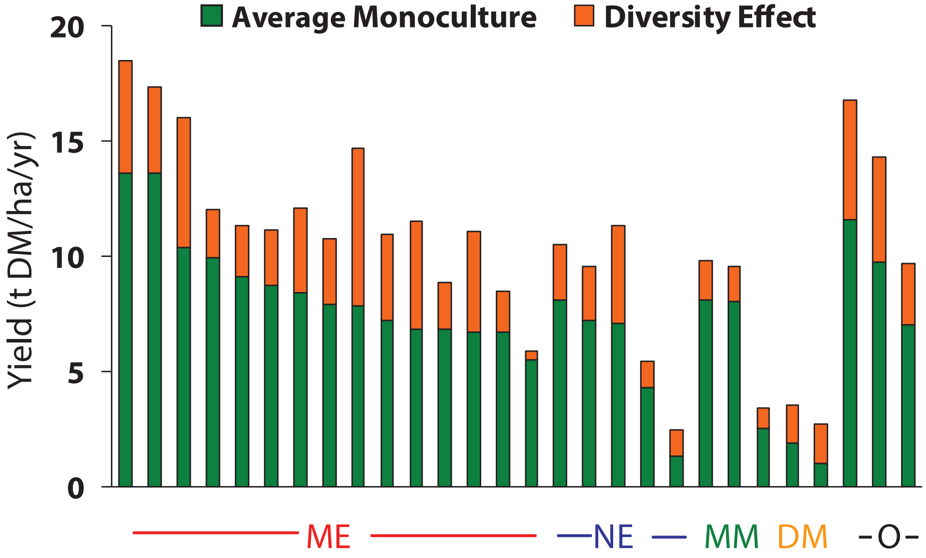

Figure 1. Yield response of grass-legume mixtures (diversity effect) when compared to either grass or legume monocultures (average monoculture) over a wide range of climatic conditions. ME: Mid-European, NE: Northern European, MM: Moist Mediterranean, DM: Dry Mediterranean. Annual application of nitrogen fertilizer ranged from 0 to 200 kg/ha (to 180 lb/ac) with a cutting frequency of 2 to 5 cuts per yr. Adapted from Kirwan et al. (2007). (1 t/ha =0.45 T/ac).

integrated in the crop rotation for 2–4 years before being ploughed and replanted with an arable (annual) crop. In contrast to most other European countries, leys with stands of pure legumes or with heavily nitrogen-fertilized grass are only occasionally found in Switzerland. The extensive and sustained success of grass-legume mixtures in Switzerland is primarily related to the added benefits of legumes mixed with grasses for both yield and quality. Even with moderate fertilizer use, dry matter yields of 14 t DM/ha/yr (6 T/ac) with crude protein contents of 17% are frequently observed (AGFF 2000). In a recent three-year experiment, grass-legume mixtures based on four species were up to 57% more productive than the most productive monoculture over a broad range of fertilizer levels (Nyfeler et al. 2009). Mixtures containing 40–60% legumes fertilized with less than 150 kg N/ha (135 lb N/ac) produced yields comparable to grass monocultures fertilized with 450 kg N/ha (400 lb N/ac) (Nyfeler et al. 2009). And the positive yield response of mixtures is not limited to moderate climates; a recent pan-European experiment confirmed the positive effects of mixtures over a broad range of climatic regions (Fig. 1; Kirwan et al. 2007). Symbiotic nitrogen fixation seems to be the most obvious mechanism contributing to the higher biomass production of mixtures. However, other possible mechanisms include improved within-season uniformity of growth (due to superior growth of grasses in spring and superior growth of legumes during summer) (Daepp et al. 2001); improved acquisition of water and nutrients; and lower variability in yield of the mixtures among years (Nyfeler et al. 2009).

Due to the ability of legumes to symbiotically fix atmospheric nitrogen, grass-legume mixtures are useful for reducing inputs of energy-intensive mineral nitrogen fertilizer into farming systems. Amounts of nitrogen symbiotically fixed by legumes range from 100 to 380 kg N/ha (90–340 lb/ac) (Boller and Nösberger 1987; Ledgard and Steele 1992). In fact, there is recent evidence that nitrogen (protein) yield in grass-legume mixtures is enhanced due to mutual stimulation of nitrogen uptake from symbiotic and non-symbiotic sources (Nyfeler et al. 2011). Mixing grasses

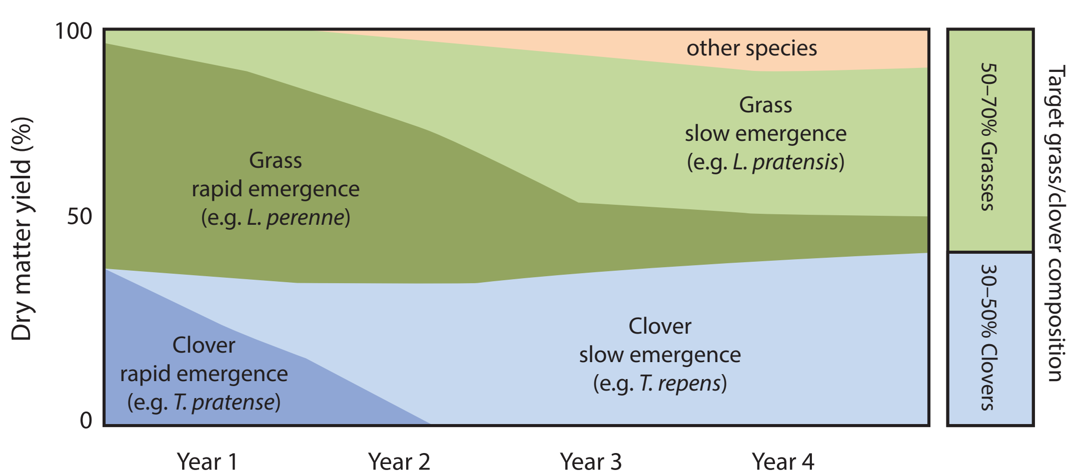

Figure 2. Principle of species exchange to ensure the grass-legume composition over time in a typical Swiss Standard Mixture (SSM). Adapted from AGFF/ART Reckenholz, Switzerland. Typical management intensities of SSM are 4 to 5 cuts or grazing with nitrogen inputs of up to 140 kg N per year as slurry or mineral fertilizer. (*P. pratensis* = Kentucky bluegrass; *L.perenne* = perennial ryegrass; *T.pratense* = red clover; *T. repens* = white clover).

with legumes enhanced the percentage of symbiotically fixed nitrogen in the legume plants and the apparent nitrogen transfer from legumes to grasses. Also, higher competitive ability of grasses enhanced nitrogen acquisition, likely due to the denser root system of grasses, despite the increase in the proportion of legume. Due to their significant concentrations of highly digestibly protein, legumes may also help to improve the protein self-sufficiency of dairy farms. Other important nutritional benefits of grass-legume mixtures compared to grasses include increased voluntary feed intake of animals and superior nutritive value due to the higher protein content and greater rumen-degradability of fiber (Ribeiro-Filho et al. 2003). Moreover, mixtures of grass and white clover make it possible to extend the optimum harvesting period without compromising forage quality (Dewhurst et al. 2009). While this aspect is helpful for all farmers with limited harvesting resources, it is invaluable when harvesting is delayed by poor weather.

Despite the overall advantages of grass-legume mixtures, it is difficult to maintain optimal proportions of legumes during the utilization period (e.g. Faurie et al. 1996; Guckert and Hay 2001). Maintaining mixtures requires attention to rates of nitrogen fertilization and frequency of harvesting or grazing. Successful forage production with grass-legume mixtures also requires availability of high-quality grass-legume mixtures with adapted species and cultivars.

Figure 3. Grass-legume mixture (early utilization stage). PHOTO FROM AGFF/ART RECKENHOLZ.

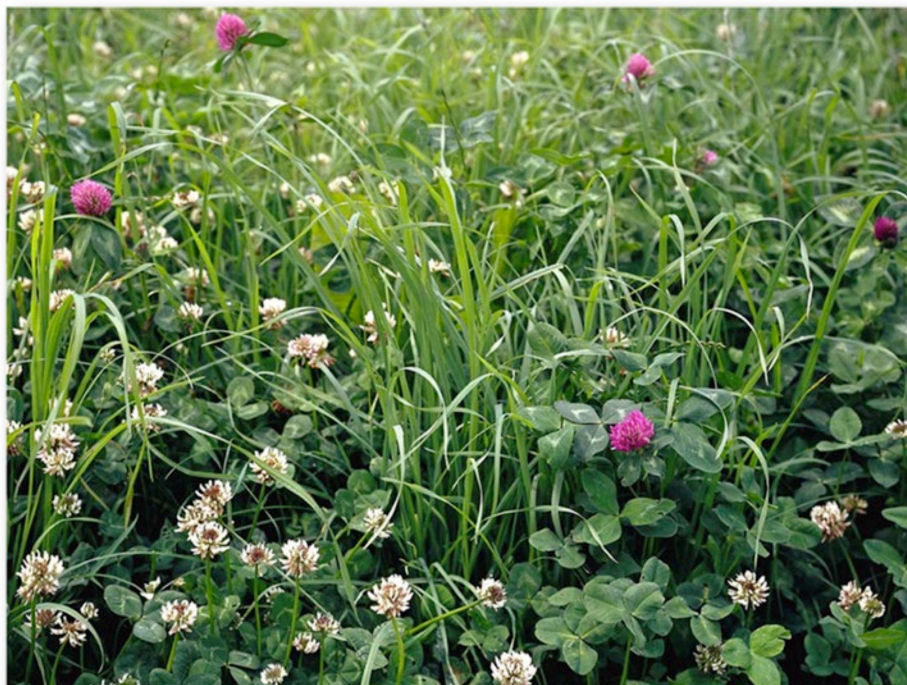

Figure 4. Grass-legume mixture with high legume proportion.

The Swiss Standard Mixture System

To ensure adapted and high quality grass-legume mixtures for Swiss farmers, a system of "Swiss Standard Mixtures" was introduced in 1955, when the first prescriptions for adapted grass-legume mixtures were published (Frey 1955). Since then, the mixtures have been continuously improved and are now revised on a four-year basis (Suter et al. 2008a). The prerequisite of high quality grass-legume mixtures is the availability of adapted cultivars. Since 1935, Switzerland has operated a breeding program for improving the most important forage grasses and legume species. Together with commercially available cultivars from other countries, new Swiss varieties are regularly tested in small experimental plots and under practical conditions in both pure stands and in mixtures at numerous sites (Suter et al. 2008b). Evaluation includes standard information such as yield, digestibility, juvenile development, date of flowering, tolerance to diseases, and winter hardiness, but evaluation also includes information on the competitive ability of the individual cultivars. Mixtures are developed for high yields but must equally fulfill many other requirements such as suitability for different types and intensities of management and harvesting practices. The critical issue of maintaining an appropriate grass-legume proportion under a broad range of management intensities is assured by combining fast emerging grass and legume species with

Table 1. Species composition of three different Swiss Standard Mixtures (SSM).

		SM 200	SM 431	SM 442
		Sowing density (kg/ha)		
Legumes				
Trifolium pratense 2n	Red clover (diploid)		1.0	1.0
Trifolium pratense 4n	Red Clover (tetraploid)	15.0		
Trifolium repens (Ladino)	Ladino White clover		2.5	2.5
Trifolium repens (Hollandicum)	Dutch White clover		1.5	1.5
Grasses				
Lolium multiflorum	Annual ryegrass	20.0		
Lolium perenne	Perennial ryegrass		3.0	3.0
Dactylis glomerata	Orchardgrass		5.0	
Festuca pratensis	Meadow fescue		8.0	
Poa pratensis	Kentucky bluegrass		10.0	10.0
Phleum pratense	Timothy		3.0	3.0
Festuca rubra	Creeping red fescue		3.0	4.0
Trisetum flavescens[a)]	Oatgrass		3.0	
Festuca arundinacea	Tall fescue			8.0
Alopecurus pratensis[b)]	Meadow foxtail			4.0

[a)]Used as component for hay production under rougher climates (alpine regions).
[b)]Used as component for moist conditions.

SM 200 has been developed for intensive 5-6 cut per yr utilization for a maximum of two vegetation periods for regions favorable to annual ryegrass *(L. multiflorum)*. SM 431 and SM 442 are designed for 3-4 cut or grazing utilizations per yr during 3-4 vegetation periods for regions favorable to *L. perenne* (SM 431) or for regions where the climate limits the successful cultivation of *L. perenne* (SM 442). For all species only successfully tested commercial available varieties are used.

slower growing, more persistent species (Fig. 2). Currently, the Swiss Standard Mixtures consist of more than 30 contrasting mixtures primarily differentiated by the duration of their utilization (1–4 years), management intensity (2–6 cuts) and climatic adaptation (Table 1). The quality assurance label of the Swiss Grassland Society (AGFF) Swiss Standard Mixtures is widely accepted by both farmers and seed companies with almost 100% of the seeds for leys sold as Swiss Standard Mixtures.

Conclusion

As compared to pure legume or grass stands, grass-legume mixtures feature numerous advantages for the production of forage for grassland based milk production systems. By their contribution to reduction of energy-intensive mineral nitrogen fertilizer inputs and to protein self-sufficiency of farms, they are an important pillar for sustainable livestock production systems

References available online at www.farmwest.com

Beat Reidy Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences, Laenggasse 85, 3052 Zollikofen, Switzerland | beat.reidy@bfh.ch

Peter Thomet Bern University of Applied Sciences, School of Agricultural, Forest and Food Sciences, Laenggasse 85, 3052 Zollikofen, Switzerland