Composition and use of seed mixtures in the high altitudes of the Alps

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Abstract
Pastures from the montane to the sub-alpine and alpine vegetation belt belong to sensible parts of the Alps. In Austria, Switzerland, Germany and parts of Italy, agricultural utilisation of such meadows is still usual. Therefore, seed mixtures used for such areas should combine different economic and ecological characteristics such as low demands on nutrients, satisfying yield and digestibility, should enable a closed sward, endurance and good adaptation on climate and soil.
At three different locations of Austria (Eschwald 1415 m a.s.l., Hochwurzen 1830 m a.s.l., Gerlos 2380 m a.s.l.), conventionall seed mixtures and seed mixtures containing useful site-specific species, were compared. With regard to altitude, different intensities of agricultural use were carried out and different economic and ecological assessments were made. Results obtained generally showed an increase of positive ecological effects on plots where site-specific seed mixtures were used. With increasing altitude, only seed mixtures with a sufficient share of site-specific species were able to guarantee a sustainable vegetation and sufficient protection against erosion.

Keywords
grassland mixtures, site-specific vegetation, alpine pasture, low-input grassland

Introduction
Mountain farming is still a very important branch of agriculture in Austria. At present, more than 833,000 ha of sub-alpine and alpine pastures are used. Constant maintenance and improvements of the pastures are necessary. Also the separation of wood and pasture in the montane vegetation belt is still an important aim of agricultural policy in Austria. In 1998, more than 400,000 ha were burdened with the right of grazing in woodland (Pötsch et al. 1998). During the last few years, several procedures of separation have been started and every year extensive areas have to be reseeded or restored (Graiss 2004). Also in the sub-alpine and alpine vegetation belt, infrastructural measures especially for winter tourism require restoration or reseeding. It is the main goal of restoration to create pastures that ensure stability against erosion, satisfactory yield and high forage quality combined with low nutrient demand and sustainability (Krautzer et al. 2003).
Two research projects have recently been carried out at HBLFA Raumberg-Gumpenstein in order to test whether site-adapted vegetation leads to more stable and ecologically site-adapted populations in comparison to commercial seed mixtures containing varieties bred for intensive grassland farming (Krautzer et al. 2003; Graiss 2004). To answer this question for agricultural used meadows in the montane, subalpine and alpine vegetation belt, plant stands originating from site-adapted and conventional seed mixtures were assessed over a period of three and four years.

Materials and methods

The effects of seed mixtures for montane, sub-alpine and alpine pastures on agricultural utilization and nature conservation were studied on three sites (Table 1).

Table 1: Description of experimental sites, mean air temperature (MAT) during the growing season (June to August, average of years) and soil chemical properties at trial establishment (Krautzer et al. 2003, Graiss 2004, Peratoner et al. 2004)

Site	Country	examination period	Altitude (m); Exposition	MAT	Soil chemical properties				
					pH_{CaCl2}	humus	N_{tot}	P (CAL)	K (CAL)
				°C		g kg^{-1}	g kg^{-1}	mg kg^{-1}	mg kg^{-1}
Eschwald	Styria, A	1999-2001	1,415; WSW	12.5	3.9	220	8.1	86	150
Hochwurzen	Styria, A	2000-2002	1,830; SE	10,8	6.6	40	2.1	13	47
Gerlos	Tyrol, A	2000	2,280; S	7,6	4.8	57	2.7	21	25

Trials arranged as plot designs with plots of 8.5 m², replicated four times, were carried out from 1998 to 2001 at the location Eschwald. Two different seed mixtures (SM1 = common conventional seed mixture according to national stipulations; SM2 = site-adapted seed mixture, containing site-adapted and site-specific grasses, legumes and herbs) were established by hand broadcasting (table 2). The plots were fertilised every year with 11,250 kg ha^{-1} mature compost.

Table 2: Composition of the seed mixtures, Eschwald (SM1 and SM2), Hochwurzen (SM3 and SM4) and Gerlos (SM3 and SM5)

grasses	SM 1	SM 2	SM 3	SM 4	SM 5		SM 1	SM 2	SM 3	SM 4	SM 5
Agrostis capillaris		7,1	4,6	4	6	leguminosae					
Avenella flexuosa					6	*Anthyllis vulneraria*				5	
Cynosurus cristatus		4,4				*Lotus corniculatus*	4,3		5	3	6
Dactylis glomerata	10,3	3,6				*Trifolium badium*				5	2
Festuca nigrescens				35	22	*Trifolium hybridum*			2,4		6
Festuca ovina			2,5			*Trifolium nivale*				7	
Festuca pratensis	17,2	11,8				*Trifolium repens*	12,9	13,4	4,2		6
Festuca supina					5						
Festuca rubra agg.	7,7	29,5	31			herbs					
Lolium perenne	16,5	5,3	15,7	3		*Achillea millefolium*			0,7	1	2
Phleum alpinum				10	6	*Campanula barbata*				0,22	
Phleum pratense	10,3	8,9	19,9			*Crepis aurea*				0,5	
Poa alpina				15	27	*Leontodon hispidus*				1	1
Poa pratensis	20,7	16	10,6			*Silene dioica*				0,03	
Poa supina				5	4	*Silene vulgaris*				0,25	1
Poa violacea				5		*Vicia sativa*			3,4		

On the sites Hochwurzen and Gerlos, exact trials arranged as two factorial split-plot designs with plots of 21 m², three times replicated, were carried out from 1999 to 2002. At the site Hochwurzen, two different seed mixtures (SM3 = usual conventional seed mixture; SM4 = site-specific seed mixture, containing sub-alpine and alpine grasses, leguminosae and herbs) were established (Table 2), using the application technique of hydro-seeding (15 g m^{-2} mineral fertiliser (15N:15P:15K), 5 g m^{-2} Rekuform®, 15 g m^{-2} synthetic binder, 15 g m^{-2} seeds). At the site Gerlos, two different seed mixtures (SM3 = usual conventional seed mixture; SM5 = site-specific seed mixture) were established, using the application technique of hydro-seeding with an additional straw mulch layer (500 g m^{-2}) in order to protect the surface from erosion (Krautzer and Wittmann 2006). With regard to the normally limited possibilities to reach and utilise such areas, the plots were only once fertilised during the setup. Digestibility was estimated using the in vitro method of Tilley and Terry (1963).

ANOVA was carried out for all comparisons. An F-ratio of $P<0.05$ was regarded as significant. For no significant differences between application techniques were found in 2001 and 2002, the results are not reported. In order to measure the ecological value of the different plots, a classification of the assessed species referring to their ecological value was made (Krautzer et al. 2005, Graiss et al. 2005). *Group 1:* site-specific species, growing naturally under site conditions. *Group 2:* site-adapted species, not site-specific but sustainable under comparable site conditions. *Group 3:* non-site-adapted species, naturally not occurring under the specific climatic and site conditions. Projective vegetation cover and botanical composition (as share of protective cover of each single species) were assessed each year. The share of all single species according to one ecological group was summarised. For the seed mixture, the total value of each group is expressed as percent by weight and the results of the field assessments are expressed as percent of projective cover.

Results and discussion

The higher the altitude and the steeper the reseeded areas, the more important is a sufficient protection against erosion. Results of several assessments indicate that at altitudes between 1200 – 2400 metres, a minimum vegetation cover of at least 70 % is required to avoid erosion (Tasser et. al. 2003). Therefore, the achievement of a sufficient vegetation cover above 70 % was an important aim on all assessed sites. Very different efforts can be found in literature in order to describe indicators for the ecological value of stands, e.g. weighted scores of the ecological indicators of Landolt (1977) or an efficiency index (Parente et al. 2002). The presented method of a grouping of species according to their ecological value allows a simple comparison of different sites and different seed mixtures.

At the site Eschwald, the conventional and the site-adapted seed mixtures showed satisfying vegetation cover over the whole assessment period (Figure 1). In comparison SM1 showed a decreasing total cover that was 10 % below SM2. An essential decrease of non-site-adapted species could be observed for both seed mixtures. For SM1, the group 3 species could not really establish and the share of species remained below 5 % in 2001. The site-adapted species established with a share of 63 % and remained until 2001. The resulting gaps were filled by site-specific vegetation immigrating from the surrounding areas. For SM2, the group 3 species decreased to a rest of 0.4 %. The site-adapted species were able to establish with a share of more than 80 % and remained stable until 2001. Because of the higher total cover of species appearing from the seed mixture and their high competitiveness, only a small share of site-specific species was able to establish. According to the soil conditions on site Eschwald, the assessed energy yield was quite low (Figure 2). No significant differences in energy yield between the two compared seed mixtures could be observed.

In general, productivity and feeding value are important characteristics for the composition of seed mixtures for pastures in the montane vegetation belt. Therefore, both mixtures on Eschwald contained non-site-adapted species, i.e. 55 % and 30 % by weight for SM 1 and SM2 respectively. The comparison clearly showed that under normal soil conditions, agriculturally useful site-adapted species were enduring in spite of the harsh climatic conditions. The agriculturally valuable but non-site-adapted species were not able to stand the site conditions and disappeared within a few years. Therefore, on moderately utilised pastures within the montane vegetation belt, the use of seed mixtures containing sustainable but also agriculturally useful site-adapted species should be favoured.

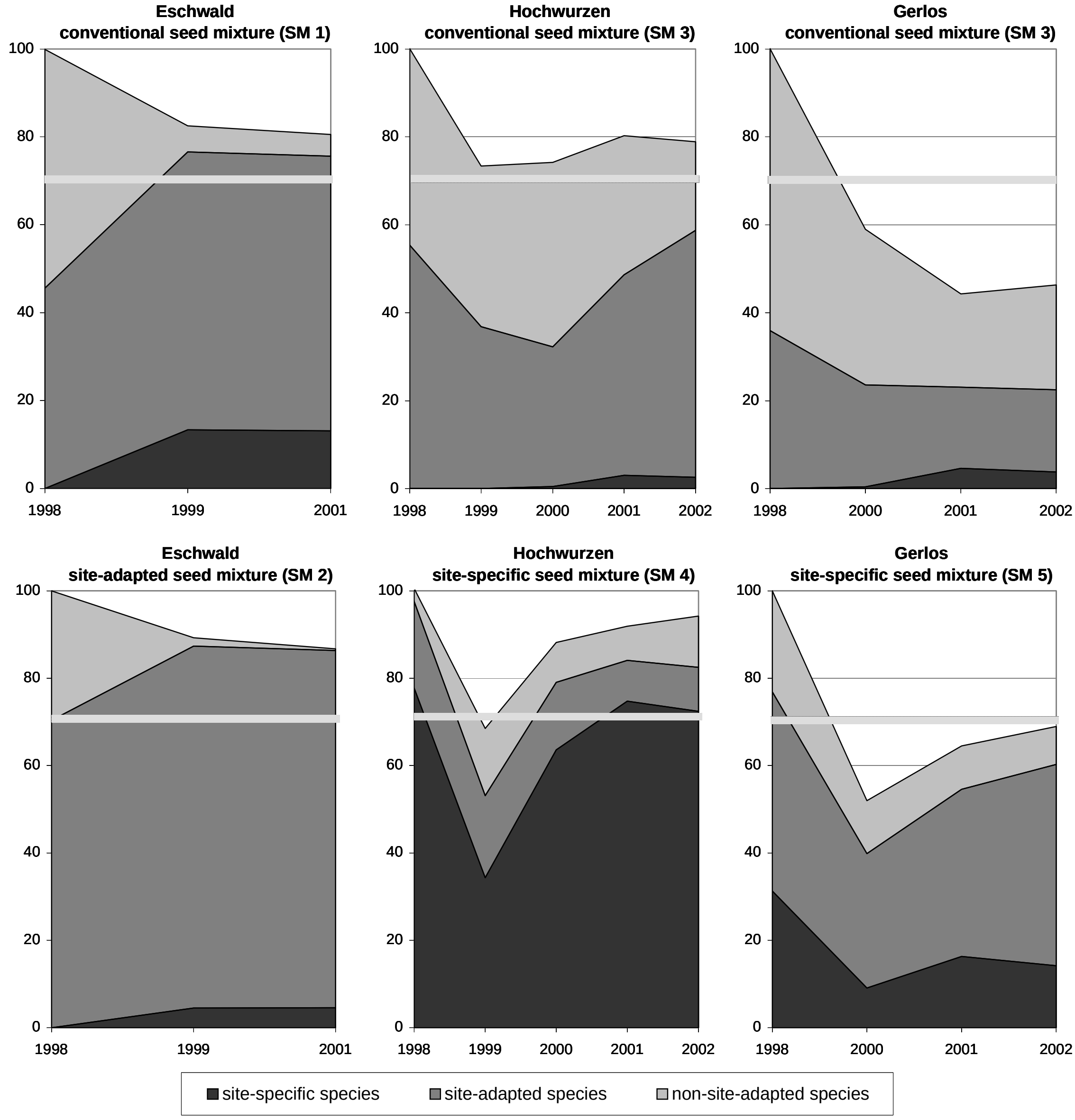

Figure 1: Average vegetation cover of grouped species referring to their ecological value on sites Eschwald, Hochwurzen and Gerlos (1998 = % by weight in original seed mixture, 1999 - 2001 = species cover in %).

At the site Hochwurzen, the conventional seed mixture (SM3) contained no site-specific species but more than 56 % of site-adapted species, mainly *Festuca rubra* (Figure 1). The total vegetation cover developed from 73 % in 1999 to nearby 80% in 2002. Since 2000, a slow immigration of site-specific species, mainly from neighbouring plots could be assessed. The share of site-adapted species decreased the first two years and reached again 56 % in 2002. The non-site-adapted species spread out for the first two years, what can be explained by the effect of fertilisation in 1999. Since 2000, their share decreased below 20 %. In total, the share of the valuable groups with expected sustainability reached 59 %. Looking at the share of species in the site-adapted seed mixture (SM4), it only contained 3 % of the non-site-adapted *Lolium perenne*, variety "Guru", as fast growing nursery crop. Nearby 78 % by weight were allocated to the group of site-specific species and around 20 % accounted for the group of site-adapted species. The total vegetation cover increased from 70 % in 1999 to 94 % in 2002, nearby 15 % higher than SM3. The ratio of the different ecological groups did not differ very much between the years of observation. The share of non-site-adapted species increased to 11 %, thereof 7 % *Lolium perenne* “Guru”, a variety that showed remarkable winter hardiness. In 2002 a share of 72 % of site-specific species and 10 % of site-adapted species could be assessed. In summary, the share of valuable groups exceeded 82 % of total vegetation cover. Due to the comparatively good soil conditions, the highest energy yields of all compared sites, exceeding 20 GJ $ha^{-1}y^{-1}$ for the plots with site-specific seeds, were assessed (Figure 2). However, no significant differences in energy yield could be assessed.

In Austria most subalpine grassland is agriculturally used during summer. Nevertheless, a fast and enduring protection against erosion that only can be reached with the help of a dense sward is the first and most important target. On short term, this can be assured by the use of a high quality application technique (OEAG 2000). In the long run, a plant stand with sustainable, site-specific vegetation that stands the harsh climatic and soil conditions at such altitudes, is necessary. The results obtained in the field trial at site Hochwurzen show that the share of non-site-adapted species and therefore the cover of plots with the agriculturally valuable SM3 continuing decreased. In a mid term evaluation, the cover will fall below the critical value of 70 %, problems with erosion can be expected. In a long-term perspective, it can be assumed that especially in the subalpine vegetation stage the lack of sustainable site-specific species would cause steady efforts and thus expenditures.

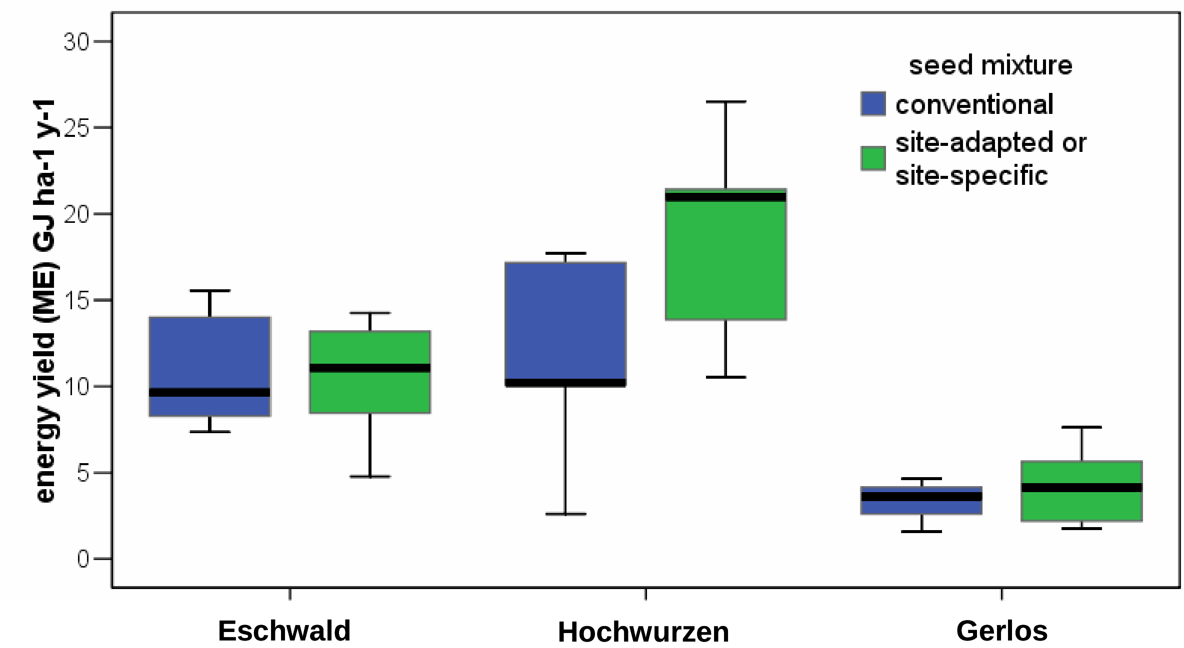

Figure 2: Average Energy Yield (ME) in GJ ha^{-1} y^{-1} at the experimental sites Eschwald, Hochwurzen, Gerlos (average 2000-2002), comparison between conventional and site-adapted resp. site-specific seed mixtures

Due to extreme site conditions on the location Gerlos, both seed mixtures were not able to establish with a satisfying vegetation cover (Figure 1). The conventional seed mixture (SM3) showed a continuous decrease for the first three years and reached a cover of 46 % in 2002. The non-site-adapted species reduced from 64 % to 24 % while the site-adapted species more or less remained the 19 % share of the original seed mixture. Site-specific species were able to fill the emerged gaps with nearby 4 %. In comparison, SM 5 showed a decreasing vegetation cover only during the first year of assessment. The two following years, the vegetation cover showed an increase from 52% to 69 %, reaching more or less the threshold for sufficient stability against

erosion. Interestingly, on this site the group of site-specific species showed a strong decrease from 31 % to 14 % against what the site-adapted species remained stable. As the site was exposed to different mechanical damages soon after the setup, a clear interpretation of this decrease is not possible. Like on all assessed sites, the non-site-adapted species also showed a strong decrease from 23 % to 8 % cover. At the extreme altitudes of site Gerlos, very low energy yields falling below 4 GJ $ha^{-1}y^{-1}$ were assessed, without differences between plots seeded with different seed mixtures (Figure 2).
In the alpine vegetation belt, most of the non-site-adapted species, suitable for grassland at low elevations, disappear after a few years. Only a few species like *Festuca rubra, Phleum pratense* and *Trifolium repens* are able to survive for a longer period. Therefore, only seed mixtures with a preferably high share of site-specific and site-adapted species can be recommended for reseeding or restoration in such altitudes. The results of site Gerlos additionally show that in some cases it is necessary to continue measures like fertilisation or reseeding up to the moment where a sufficient vegetation cover is being reached.

Conclusions

According to the limited climatic and soil conditions of most meadows and pastures from the montane to the alpine vegetation belt, it becomes more and more important to choose species suitable to the prevailing site conditions. A comparison of the assessments of the three trials in three different vegetation belts clearly showed, that due to the worsening conditions and the naturally low intensity of land-use, site-adapted and site-specific species become more and more important with increasing altitude. Collaterally, the possibility and feasibility for agricultural use and fertilisation of such sites decreases with altitude.
On moderately utilised pastures or meadows in higher altitudes, no decrease of energy yield can be expected if site-adapted or site-specific seed mixtures are used for reseeding.
In the montane vegetation belt, seed mixtures containing site-adapted but agriculturally useful species should be favoured. In the sub-alpine and alpine vegetation belt, only seed mixtures containing a high share of site-specific and suitable site-adapted species are able to guarantee a sustainable vegetation and sufficient protection against erosion what generally is the first and most important target if reseeding or restoration activities are necessary. Only such species are able to stand the harsh climatic conditions of such sites. They ensure sustainable vegetation with a sufficient long-term protection against erosion processes.
The suitability of site-adapted and site-specific seed mixtures for agricultural purposes could also be proved in several former publications (Krautzer et al. 2003, Graiss 2004, Peratoner et al. 2004, Graiss et al. 2005, Krautzer et al. 2005).

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