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Summaries of diploma and PhD theses (1998)

Diploma theses (12)

Correlations between farm structure and ecological value of the agricultural landscape

Zusammenhang zwischen Betriebsstruktur und landschaftsökologischer Leistung von Landwirtschaftsbetrieben; 32 pp.

CHRISTOPH BUHOLZER

1 Two contrasting processes control the present development of the Swiss agriculture. On the one hand, do worldwide economic constraints lead to structural changes in the agricultural systems. A new federal policy, on the other hand, tries to stop and eventually to reverse the well known decline in agrobiodiversity. These processes run in parallel and seem to be mutually dependent.

2 The central hypothesis of the diploma thesis is that there are correlations between farm structure and the ecological value of the landscape. This hypothesis was tested for 42 farms in the lowlands of the Canton Zurich (Uster, Fehraltorf, Illnau).

3 In 48% of the total area surveyed the quality of the "ecological compensation sites" was good. Biodiversity in hedgerows was particularly well developed, especially in those which were not recently planted. However, the ecological value of extensively managed or mod-

erately intensive meadows was usually not high, although these vegetation types cover large areas. The same was true for most orchards.

4 There was a clear positive correlation between the percentage of compensation sites on the total farm area and the ecological value of these sites. Diversity was higher on farms of part-time farmers. No correlation was found between the ecological value of the "farmscape" and farm size, production type, density of cattle, age or professional training of the farmer.

5 The occurrence of marginal land seemed to be most important for the quality of the ecological compensation sites within a farm. Part-time farmers tended to manage their land less intensively which often led to a higher ecological value on the farm scale. The past intensity of agricultural management was also crucial for the present patterns in biodiversity.

Seed rain in alpine grassland

Diasporenregen im alpinen Grasland; 88 pp.

ULI FAIGLE

1 Seed rain was studied in alpine grassland at the Jakobshorn Mountain in the surroundings of Davos (c. 2500 m a.s.l.) with use of dry funnel traps. Some of the five studied plots, respectively situated on SW- and NE-slopes, had already been studied one or two years be-

fore. The study included the density of the seed rain, species number (= alpha diversity) and also species composition in particular plots compared with the standing vegetation. The results were compared to those obtained in previous years.

2 The seed rain density varied between 384 and 3719 diaspores m⁻² in individual plots with a mean of 1492 ± 297 .

3 On the whole, seed rain included 28 species; nine of those species apparently represented diaspore input from distant sources. Mean seed species number per plot was 2.2–5.5; seed rain was mostly dominated by a few species. The plant cover of individual plots was only partly represented in the seed rain (one-third to more than a half of all species).

4 Compared to the study years 1996 and 1997, seasonal patterns of seed rain in 1998 were comparable but the seed rain started about two weeks earlier and its density was also the highest. The particularly good weather conditions throughout the summer 1998 clearly played an important role in this respect. On the other hand, no distinct differ-

ences in species number were found among years.

5 Possible influence of spatial variation on seed rain was studied in relation to different exposition, slope, and altitude. Significant differences in seed rain density and species number were found between SW- and NE-slopes; the situation in the NE-facing plots was apparently more advantageous. Differences in altitude were reflected in significant differences between species number but not in the density of seed rain. On the other hand, differences between plots representing different slopes were not significant.

6 The results of the study are pertinent to both basic research and restoration of high-alpine ecosystems since grassland represents an important diaspore source for colonisation of alpine disturbances.

The influence of some polycultures on selected insect pests

Der Einfluss von ausgewählten Mischkulturen auf den Insektenbefall; 57 pp.

RAHEL GESSLER

1 The literature on biological gardening has suggested that polycultures may reduce garden pests. Here I tested the effects of various polycultures on insect pests.

2 The oviposition of the large white butterfly (*Pieris brassicae* L.) was observed in monocultures of turnip-cabbage (*Brassica oleracea* ssp. *oleraceae* L.) and in polycultures of turnip-cabbage with wormwood (*Artemisia absinthium* L.) or tomato (*Lycopersicon esculentum* Mill.) in a pot experiment in a shadehouse.

3 In further monocultures of turnip-cabbage certain plants were treated with home-made extracts of wormwood or tomato. The same extracts and an additional industrial extract of wormwood were used in dual-choice feeding experiments with the larvae of *P. brassicae*.

4 Only the plants treated with the tomato extract had a significant smaller number of eggs. The same extract and the industrial wormwood extract significantly inhibited feeding of the larvae. The effect of the tomato extract is probably due to the toxic alkaloids solanine and tomatine. The industrial wormwood extract had probably a higher concentration of active substances than the home-made extract.

5 In a further field experiment settlement and development of the black bean aphid (*Aphis fabae* Scop.) in monocultures of kidney-bean (*Phaseolus vulgaris* L.) and polycultures of kidney-bean with summer savory (*Satureja hortensis* L.) were observed.

6 Contrary to prediction *A. fabae* settled on both cultures in the same number and devel-

oped much better in the polyculture. The better development in the mixed culture might be due to a better nutritional state of *P. vulgaris* or to a more evenly spread of *A. fabae* in the mono-

culture. It might also be possible that the smell of *S. hortensis* masked the smell of the infected bean plants, which would otherwise have attracted predators and parasitoids of *A. fabae*.

Immediate effects of an experimental fire on the arthropod fauna in southern Switzerland

Der direkte Einfluss des Feuers auf die Arthropodenfauna bei einem Waldbrandexperiment im Kanton Tessin; 75 pp.

SABINE HERZOG

1 The thesis investigated the immediate impact of forest fire on arthropod abundance and diversity. At the end of March 1998, 0.23 ha of chestnut forest near Bellinzona/TI was experimentally burned. To quantify the impact on the arthropod fauna, pitfall traps, flight interception traps, photoelectors and a dry extraction method (Berlese) were used. In addition, at the end of the prescribed fire, the ash was searched for killed animals.

2 The arthropods were affected differently by the fire, depending on the substrate layer they inhabited. The soil arthropods were not significantly reduced, as the heat did not penetrate the soil very deeply. In the litter, most taxa were

heavily affected, but the differences among taxa were considerable. The numbers of spiders were reduced by 70%, whereas 12% more myriapods were collected after the fire. The epigeous arthropods, which were not directly killed by the fire, were disturbed drastically by the fire-induced habitat disturbance. As a consequence, the arthropods became more active and left the burned site. Insects capable of flight were at this time of the year not very active and therefore less influenced.

3 As the fire experiment in late winter did not take place in a period of high arthropod activity the immediate impact of fire on the arthropod fauna was rather low.

The effect of plant species diversity on pathogen infection and herbivorous damage on grassland perennials

Zum Einfluss der Artendiversität auf Pathogeninfektion und Herbivorie bei perennierenden Grünlandarten; 118 pp.

MARTIN LANDOLT

1 In this experimental study I evaluated how plant species diversity affects fungal infection and damage by herbivores on grassland perennials. A generally accepted theory suggests that disease spreads easier in grasslands with low biodiversity, since host plant density is high and physical barriers are lacking. Similarly herbivorous damage is expected to be more severe in low-biodiversity grasslands because of high

resource concentration, and because of low presence of natural enemies.

2 In Lupsingen, Switzerland, a manipulated experimental field was established in spring of 1995. Thirty-two different species diversities in two replicas, ranging from monocultures to average native grassland community, were planted with 48 plant species. Of ten leading grassland species, seven were analy-

zed in the fourth season after establishing the field: *Dactylis glomerata*, *Poa pratensis*, *Lolium perenne*, *Arrhenatherum elatius*, *Trisetum flavescens*, *Trifolium repens* and *Plantago lanceolata*. For the analysis two different categories were used. Plant diversity level, ranging from monoculture to 2-species, 4-species, 8-species and 32-species, and functional groups, consisting of combinations of grasses, legumes and non-legume herbs.

3 By diversity level as well as by functional group, fungal infection was in general greater in the monoculture than in the highest species richness. The intermediate plots showed of-

ten an irregularity, some plots being infected to a higher or lower degree than expected from the overall trend. These exception could be explained by inspecting the species composition and the vegetation cover.

4 The herbivorous damage was not consistent to any trend. Damage of possible specialist insects, for example chew-strips on grass leaves, showed strong increase in some intermediate plots. Holes in the leaves caused by generalist herbivores, however, had an irregular and inconsistent distribution over the plots and their replicas. Functional groups could not give any clear explanation either.

Food choice behaviour of food by red deer (*Cervus elaphus* L.) on two subalpine grasslands in the Swiss National Park

Futterwahlverhalten des Rothirsches (Cervus elaphus L.) auf subalpinen Wiesen im Schweizerischen Nationalpark; 67 pp.

KATHRIN MÄRKI

1 The goal of this study was to investigate the food choice behaviour of various classes of red deer (*Cervus elaphus* L.) in the region of the Swiss National Park and to learn about the effects on such behaviour. Possible effects on vegetation caused by selective behaviour were investigated. Red deer was studied on the two subalpine grasslands "Il Fuorn" and "Praspöl" from May to September 1996. Data were collected by direct observation and subsequent investigation of the grazed area. To this end, the bitten and not bitten plants were counted. From this, the constancy of plants that had been browsed, the selection process as well as the proportion of the various species in the grazing area could be determined.

2 The plant communities of both areas were mosaics of a Crepidio-Festucetum and a Koeherio-Poetum xerophilae, and showed large differences despite comparable altitudes. Furthermore, "Il Fuorn" had large areas of mo-

saic structures in addition to the dominant vegetation while the grassland "Praspöl" was topographically more structured with small buckels and hollows.

3 On "Il Fuorn" the mosaic areas, consisting mainly of *Brachypodium pinnatum* (L.) P.B., *Blasmus compressus* (L.) Link or *Elyna myosuroides* (Vill.) Fritsch, were completely avoided by the deer. Gradually the grazing areas were concentrated on one particular sector of the pasture. Here the vegetation was naturally kept shorter. On "Praspöl" at the beginning of the season, the small buckels were grazed intensively while later on, the high-grown vegetation in the hollows was increasingly used. Towards autumn on both pastures there were areas on which *Festuca rubra* L. s.l. and *Trifolium repens* L. became dominant; these areas were continuously grazed.

4 Most species showed a propensity for being browsed to over 50%; the fact that they were

browsed more often was not connected to their abundance. The few species with infrequent browsing were scarce.

5 The proportion of grazing and the abundance of the plant species were correlated to the various classes of deer. On "Il Fuorn", the most abundant plant species accounted for 80% of the food for young deer, whereas the grazing proportion of the same species by the hind amounted to only 60%. On "Praspöl" the proportion of grazing was similar to all deer.

6 On "Il Fuorn" selective behaviour could be ascertained for all classes of deer, on "Praspöl" only for the hind; whereby the selectivity values of the plant species were very different according to the various classes of deer. Scarce species were avoided by the young deer but often strongly favoured by the hind.

7 From the plant species present on "Il Fuorn" and "Praspöl", one half showed simi-

lar selectivity values, the other half was partly used in a very different way.

8 Variability in time could only be determined to a limited degree: from May till September the most abundant plant species were either constantly avoided or constantly favoured. However, the degree of selectivity decreased with time.

9 Particular grazing habits of individual deer were hardly evident: on "Il Fuorn" the plant species were all used to the same degree by the majority of hind.

10 Two distinct grazing habits were determined for the hind: selective behaviour was significantly stronger on pasture which had not yet had too much grazing than on pasture which had been intensively grazed already.

11 Long-term changes in the vegetation seem therefore primarily due to the loss of nutrients as a result of intense grazing rather than to selective behaviour of the deer.

Interactions between ants, *Euphorbia cyparissias* and its pathogenic rust fungi

Interaktionen zwischen Ameisen, Euphorbia cyparissias und pathogenen Rostpilzen; 20 pp.

STÉPHANIE SCHÜRCH

1 Ants and plants often occur in the same communities and occasionally form mutualistic relationships. For example, ants disperse the seeds of some plant species and defend some other species against herbivores. However, ant pollination is very rare.

2 *Euphorbia cyparissias* has a known mutualistic relationship with ants for seed dispersal. Ants also forage on the floral nectar of *E. cyparissias* and represent a large proportion of its flower visitors. I therefore examined with an exclusion experiment whether ants pollinate *E. cyparissias*. I also conducted hand pollination to determine the mating system.

3 *Euphorbia cyparissias* is also the host of rust fungi of the *Uromyces pisi* species complex.

The fungi produce spores mixed with nectar on the infected stems. Insects are required to transport these sexual spores between the different mating types of the obligatory outcrossing fungi, very much like pollination by higher plants. Ants are often observed foraging on these infected stems. I thus also asked whether ants fertilise the pathogens of *E. cyparissias*.

4 In the experiment to determine the mating system of *E. cyparissias*, seed set was not possible without pollen: *E. cyparissias* is not an apomictic species. However, self-pollinated flowers set seeds, indicating that *E. cyparissias* is self-compatible. Plants from which insects were excluded set far less seeds than unma-

nipulated controls to which insects had free access. Thus, although *E. cyparissias* is self-compatible, it did not self-pollinate and therefore relies on insects for pollination.

5 In the exclusion experiment, plants visited only by ants set seeds more often than plants from which all insects were excluded; thus, ants did pollinate *E. cyparissias*. However, the reproductive success of plants visited only by ants was lower than that of plants visited only by winged insects or of plants visited by all types of insects. It seems that among the plants to which only ants had access, some

were completely ignored and did not set seeds, and some were regularly visited and set as many seeds as plants visited by all insects. This pattern can be explained by the behaviour of the ants, as they regularly go back to the same foraging site as long as they are rewarded with food.

6 To find out whether ants fertilise the pathogenic rust fungi, a second exclusion experiment was conducted, this time with infected stems. The fungi failed to reproduce on the majority of the stems visited only by ants. Ants did not fertilise the rust fungi.

Factors controlling seed dispersal of *Sambucus nigra* in forest gaps

Zur Ausbreitungsökologie von Sambucus nigra auf Lichtstandorten im Wald; 47 pp.

THOMAS STÜDELI

1 This thesis investigates the factors which may control seed dispersal of *Sambucus nigra* in forest gaps. The main objective was to investigate how bird-mediated dispersal is controlled by a *S. nigra* shrub itself, by the surrounding vegetation and by the adjacent landscape. The field sites were selected in the northern parts of the Swiss lowlands near Grenchen, in a mixed beech forest on the southern slope of the Jura mountains at 450–800 m a.s.l.

2 The bird-mediated secondary seed rain (*SSR*) was recorded with 72 traps (0.7 m x 0.7 m) in 24 forest gaps of different size and different age between July and November 1997. In each gap two traps were placed under a fruiting individual of *S. nigra* and one trap under a shrub of similar structure which grew in a distance of 4–10 m and where all flowers were mechanically removed.

3 In total 69,000 seeds of 22 fleshy-fruited species were collected. The influence of the shrub itself: The *SSR* was correlated with the length of the branches directly over the trap,

and with the amount and the density of fruits on the shrub. The influence of the near surroundings: The *SSR* was correlated with the amount of fruits available within a radius of 10 m in the gap sites. This correlation was stronger for the not fruiting shrubs. The *SSR* under fruiting shrubs was correlated with *SSR* under the not fruiting bushes in the same gap. The influence of the landscape: The *SSR* was correlated with the size of the forest gap. This result could be an effect of the increasing amount of fruits in larger gaps, as well as a consequence of a warmer microclimate in larger gaps. The *SSR* was only poorly correlated with the diversity of the forest vegetation within a distance of 150 m. There was also no significant relation between the *SSR* and the length of the inner and outer forest edges in the surrounding landscape.

4 Quantity and quality of fleshy-fruited vegetation may have a considerable influence on the activity of frugivorous passerines. The higher the density of fleshy-fruited species in a forest stand, the more new fleshy-fruited

plants are introduced, especially in forest gaps. The attractivity of *S. nigra* for frugivorous birds can be used as a natural tool to in-

crease biodiversity in forest plantations. The results can be used as an argument to increase gap diversity by forest management.

Experimental study on seed rain in alpine ski runs

Experimentelle Untersuchungen über Diasporeneintrag in alpinen Skipistenplanierungen; 112 pp.

KARIN THIELE

1 Seed rain in a machine-graded ski run and in an intact grassland was studied throughout the vegetation period 1998 at Jakobshorn (surroundings of Davos, NE-Swiss Alps, 2500 m a.s.l.). The study included seasonal fluctuations, density and species number (alpha diversity). The species composition of the seed rain was compared to that of the standing vegetation. The results were compared with those of the previous years.

2 Two different trap types were used on the ski run: (a) the dry funnel traps routinely used in other projects, and (b) artificial lawn pieces simulating the plant cover. The latter traps were installed to assess possible influence of spatial vegetation structure upon the seed rain.

3 Mean density of the seed rain on the ski run was 858 ± 142 seeds m^{-2} . The maximum density was registered by the end of August; on the other hand, the highest alpha diversity occurred one month later. The studied plots of the ski run differed from each other with regard to the seed rain density and species number; some of these differences were highly significant. Compared to the previous study years, the seed rain in 1998 was clearly higher than in 1996 or 1997. The results confirm the important influence of weather conditions on the reproduction by seed in alpine plants.

4 Mean density of the seed rain in the studied grassland was 3383 ± 1156 seeds m^{-2} . Both

the maximum density and the highest alpha diversity were registered by the end of September. The results were not significantly different from those obtained in 1997.

5 Density and diversity of seed rain on the ski run differed from that in the grassland, and these differences were highly significant. The temporal shift in the occurrence of maximum seed rain is at least partly related to the different plant species composition of either site. Only few species prevailed in the seed rain both in the ski run and the grassland. Herbs were most frequent in the former site, whereas in the latter one graminoids clearly predominated.

6 The majority of species identified in the seed rain occurred also in the standing vegetation and thus possibly represented the natural seed shadows. Species coming from outside the plots (= diaspore input) were more frequent in the ski run than in the grassland.

7 No significant differences in seed rain were found between the funnel traps and the artificial lawn pieces, but it was rather difficult to take out all diaspores from the latter traps. It seems thus that vegetation structure may enhance a definite diaspore entrapment at the site of their primary deposition.

8 The results of the study contribute to a better assessment of dispersal in the alpine vegetation belt, and are also helpful to planning and implementation of restoration schemes.

Investigation of vegetation dynamics at the Tagliamento based on aerial photographs and GIS

Luftbild- und GIS-gestützte Vegetationsuntersuchungen am Tagliamento; 64 pp.

MARIO VIELI

1 In river ecosystems natural disturbances due to flow and sediment regimes determine ecological patterns and processes across a range of scales. The dynamic nature of rivers causes the enormous biodiversity of riparian vegetation. It is the lack of dynamics as a consequence of flood control measures, i.e. regulated discharge and constrained channel migration, that accounts for reduced habitat heterogeneity and losses of functional integrity in many European rivers.

2 The aim of this diploma thesis was to set up a methodical procedure for monitoring the development of riparian vegetation on gravel bars in the braided section of the Tagliamento in NE-Italy. The vegetation was classified on a floristic basis to investigate successional processes in the floodplain. These data were also used to verify the interpretation of the aerial photographs. With the photographs, the large scale changes of the landscape could be studied. Due to the variable projection geometry of these datasets, a geometric correction was essential. Field work was done in summer 1997, and aerial photographs of 1984, 1986 and 1991 were analysed.

3 The following methods were applied: (1) A survey of the vegetation in the study area (species lists, dendrochronological age determination), (2) classification of the vegetation on the basis of morphological and floristic characters, (3) geometric correction of the aerial photographs, (4) mapping of the vegetation types on each of the aerial photographs, and (5) analysis

of the digital datasets and interpretation of the changes with the help of the field survey, hydrological data and the literature.

4 The active zone of the Tagliamento in the study area experienced major changes between 1984 and 1991. The development of the vegetation on the gravel bars follows apparently a cyclic dynamics through four major stages: (1) gravel bars, (2) large woody debris and small pioneer islands with shrubs, (3) young islands dominated by *Salix* spp., and (4) mature islands with trees mainly of the genera *Populus*, *Salix* and *Alnus*. Large woody debris were frequently deposited near the active channel and on gravel bars, and thus play a key role for plant colonization in an otherwise inhospitable alluvial environment. The successional development from gravel bars to the island stage takes about 10–20 years. All successional stages are subject to erosion by major floods. Erosion of woody islands sets free large trees which are transported by the river, deposited downstream where they may initiate successional processes again.

5 Considering the threat to riparian landscapes and the need to protect them the methods used in this thesis are critically discussed concerning their suitability for ecological monitoring. GIS analysis based on remote sensing has proven to be very useful. However, for best results the temporal resolution of the aerial photographs should be enhanced to fit with the exceptional dynamics of riparian ecosystems.

Dispersal of *Geranium purpureum* along railways in Switzerland, Germany and Austria

Geranium purpureum. Zur Ausbreitung einer Pflanzenart auf Bahnarealen der Schweiz, Deutschlands und Österreichs; 29 pp.

JUTTA WALTER

1 A sudden expansion of *Geranium purpureum* on railway areas in Switzerland, Germany and Austria has been reported since the early nineties.

2 *Geranium purpureum* ($2n = 32$) is a close relative to *G. robertianum* ($2n = 64$). The hybrids of the two species are nearly indistinguishable from *G. robertianum*, except in their sterility.

3 The natural geographical range of *G. purpureum* is essentially the Mediterranean basin. It behaves as a pioneer or ruderal plant and is often found in places with extreme microclimatic conditions, for example on poorly developed, stable soil (rocks, gaps in walls, sand, garigue). Further south it also exists in shaded habitats and on moist soil.

4 Normally, the annual plant germinates in winter or spring, but on railtracks already in summer or autumn, so that it overwinters as a rosette. *Geranium purpureum* does suffer from low winter temperatures, but no details are available about its tolerance level. The existence of *G. purpureum* in eastern Switzerland for more than forty years, populations of smaller plants in Kärnten (Austria), and its appearance in more continental zones have led to the assumption that there might be another, east-mediterranean type of *G. purpureum*, which overwinters as a fruit. It would be interesting to know more about this biotype.

5 *Geranium purpureum* dies in early summer. This is thought to be a strategy to avoid the

extreme conditions of this season. Nevertheless, there are references to plants flowering in late summer and fall: They probably originate from fruits of the vernal cohort.

6 For long distances *G. purpureum* is likely to have been dispersed by train. The comparison of the patterns in fruit capsules leads to the conclusion that the immigration has originated in different populations. It is uncertain whether populations from western Switzerland have been involved in the expansion. However, it is not likely that the population of eastern Switzerland has contributed to the spread, either. Maps with places where the species has been found lately in Switzerland and Germany have been made.

7 Recently, *G. purpureum* could become more abundant on railway areas because of changes in herbicide use since 1989. Its life-cycle is completed in most cases at the time of the herbicide application in early summer. Probably the climate in the Swiss Midland has already been favourable for *G. purpureum* before its actual expansion. But more cannot be said without investigations into its tolerance to cool temperatures.

8 The present occurrence of *G. purpureum* is limited to the warmest parts of the Swiss Midland. So far, the plant is only growing on railway areas. It is a pioneer species on sparse places which are often disturbed. Because of its heavy fruits and the high light demand of the species further expansion is to be expected along roads.

Effects of sown wildflower strips on spatial and temporal dynamics of different slug species in reduced tillage winter wheat

Auswirkungen von Buntbrachen auf die räumliche und zeitliche Dynamik verschiedener Nacktschneckenarten in Winterweizen mit reduzierter Bodenbearbeitung; 79 pp.

RICHARD ZWEIFEL

1 To promote beneficial insects and rare wild plant species, wildflower strips are sown at the edge of arable fields. However, there is evidence that these strips do not only favour beneficial insects, but provide a suitable habitat for slugs as well. Since slugs are known to be important pests in crops such as wheat and potato, detailed knowledge of the effect of wildflower strips on different slug species is desirable. In order to assess the potential negative effect that sown wildflower strips may have by promoting slugs, it is essential to know how far the slugs present in flower strips move into the adjacent crop areas. A better understanding of the effect of wildflower strips on the spatial distribution of different slug species is also vital for site-specific pest management in a new system known as *precision farming*.

2 In the thesis, the effect of sown wildflower strips on spatial distribution of different slug species was investigated in experimental reduced tillage wheat plots at Schafisheim in Canton Aargau (Switzerland). In addition, different herbicide treatments (i.e. pre-emergence and post-emergence application of herbicides) were compared in their effect on slug numbers. Spatial and temporal dynamics of different slug species were also discussed in relation to other factors, such as neighbouring crops, crop rotation and weather conditions.

3 Cucumber-baited traps were placed at 4 m, 8 m and 12 m distance from wildflower strips in the wheat crop. In addition to that, traps were also placed in the flower strips and at the edge between the flower strips and the adja-

cent crop area. There were three replicates at each distance. In control plots, traps were arranged in the same pattern. Three plots bordered by wildflower strips and three control plots were studied. Each plot was subdivided into two subplots, where the herbicides were applied before (subplots a) and after (subplots b) the emergence of the crop, respectively. Four samplings were conducted in both the subplots a and b between May and July 1998.

4 The mean number of *Arion lusitanicus* caught was higher in the crop areas adjacent to the flower strips than in the control plots. On certain dates and in certain plots, numbers were particularly high in the flower strips and declined with the distance from the strips. In other cases, however, numbers of this species trapped were similar or higher at 12-m distance than in the strips themselves. These findings indicate that *A. lusitanicus* may be promoted up to a distance of at least 12 m from flower strips. As the variation between different plots and dates was large, factors other than the wildflower strips, e.g. the size of the population or weather conditions, must have influenced the distance *A. lusitanicus* moved from the flower strips into the crop areas.

5 Contrary to *A. lusitanicus*, *Deroceras reticulatum* was never caught in higher numbers in the flower strips than in the control plots. Yet, it was found that numbers of this species increased with the distance from the edge of the plots, when the crop was well developed. *Deroceras reticulatum* was found to be largely unaffected by adverse weather conditions, as numbers caught increased steadily with time.

6 *Arion distinctus* and *Arion carinarion* were caught in much smaller numbers than *D. reticulatum* or *A. lusitanicus*. They were more frequently found in the control plots than in the plots bordered by wildflower strips. Hence, these species were not promoted by wildflower strips. *Arion carinarion* showed a high degree of aggregation, for slugs of this subgenus were found in relatively high numbers in a control plot at a certain distance from the wildflower strip, but were only rarely observed in the other plots. *Arion distinctus* was also aggregated in certain plots, but less clearly than *Arion carinarion*. *Arion distinctus* and *A. carinarion* were trapped in very small numbers when conditions were unsuitable for slug activity and trap catches of

these species were in agreement with certain weather parameters. *Arion distinctus* catches corresponded well with the amount of rain that had fallen on the preceding days.

7 *Deroceras reticulatum* was found much more frequently in the subplots b than a. Therefore, the application of herbicides after the emergence of the crop seems to be less harmful to *D. reticulatum* than pre-emergence application. However, since different herbicides were used in the two subplots and the samplings in the subplots a were not carried out on the same date as in the subplots b, further research is necessary to confirm these results. In the other species, the differences between the two herbicide treatments were less pronounced.

PhD theses (3)

Herbivore-induced volatiles in maize repel the corn leaf aphid, but attract natural enemies of herbivores

Durch Herbivore induzierte Duftstoffe vertreiben Blattläuse auf Maisblättern und ziehen natürliche Feinde der Herbivoren an; 103 pp.

MARCO L. BERNASCONI OCKROY

1 In the last 10 years, herbivore-induced emission of chemical signals in plants have been the subject of intensive studies and convincing data have been obtained on its ecological and entomological significance. Detailed studies of maize, *Zea mays* L., provide us with considerable insight into different aspects of the trophic interactions between plants, their herbivores and the natural enemies of the herbivores. In maize the release of specific volatiles can be induced by mechanical damage to the leaves and treatment of the damaged sites with caterpillar regurgitant. Recently, the active factor in the regurgitant of the caterpillar has been isolated and identified.

2 Despite the enormous increase of information on this phenomenon important questions remain unanswered. Some of them are addressed here: (1) Do herbivore species with contrasting feeding habits induce different volatiles in maize? (2) Are herbivores themselves affected by the induced volatiles? And (3) what is the influence of the odour bouquet of different maize genotypes on the host-location behaviour of herbivores? (4) Can the attractive effect of the induced volatiles on parasitoids and predators, as observed in the laboratory, be reproduced under field conditions?

3 We compared the volatile emissions induced in maize plants by *Spodoptera littoralis*

(Boisd.), a folivorous caterpillar, *Ostrinia nubilalis* Hübner, a stemborer, and the aphid *Rhopalosiphum maidis* (Fitch). Plants infested with *S. littoralis* emitted the greatest quantity of volatiles. In addition to induced volatiles, *S. littoralis* caused the maize plants to emit large amounts of green leaf volatiles throughout the whole experiment. Plants infested by *O. nubilalis* emitted the same blend of volatiles, but in much smaller quantities and the green leaf volatiles were not produced. *Ostrinia*-damaged plants also emitted some highly volatile compounds which may either come from the frass of this insect or be emitted from the damaged plant stem. The aphids induced no measurable emissions of volatiles in the maize, even after heavy infestation.

4 We investigated the response of *R. maidis* to induced volatiles in laboratory and semi-field studies. In a Y-tube olfactometer significantly more aphids chose the odour of healthy, undamaged maize seedlings when tested against clean air or plants treated with regurgitant. Clean air was chosen more often when tested against the odour of treated plants. The apparently repellent effect of the odour of treated plants was significant for winged aphids, but not for the wingless aphids. In the field experiments, significantly fewer winged and wingless aphids settled on treated plants than on healthy plants.

5 In Y-tube olfactometer experiments we tested the aphids *Rhopalosiphum maidis* (Fitch) and *Rhopalosiphum padi* (L.) to the odours of the two maize varieties LG1 1 and Delprim (*Zea mays* L.). The odour of each variety was also tested against clean air. For these experiments we used a method to collect simultaneously volatiles from the exposed plants. This procedure enabled us to correlate the aphid behaviour with the volatiles produced by the two varieties. Winged and wingless *R. maidis* and wingless *R. padi*

significantly preferred the odour of LG1 1, whereas winged *R. padi* chose the odour of Delprim and seemed to be repelled by odour of LG1 1. Analysis of volatile collections showed significant differences between the two varieties in the composition of compounds which may explain the results of the behavioural experiments.

6 In three different field experiments we investigated whether or not natural populations of parasitoids and predators were attracted to the induced volatiles. The insects were trapped on blue sticky traps placed next to each plant (1st, 2nd experiments) or at different distances from the plants (3rd experiment). In the 1st experiment the total number of entomophagous insects was significantly higher on traps near treated plants than near healthy plants. However, this difference was not significant for individual insect groups that were trapped (Hymenoptera: Terebrantes; Diptera: Syrphidae; Heteroptera: Anthocoridae), neither in the 1st nor in the 2nd experiment. In the 3rd experiment, the higher catches of parasitoids near treated plants and the increased presence of these insects on the down-wind side of treated plants support the notion that herbivore-induced maize odours also attract natural enemies of maize pests in the field.

7 Herbivore-induced plant odours are common and can affect insects from different trophic levels. The response to herbivory can differ significantly depending on which herbivore feeds on a plant. These differences, however, are only obvious in the quantities that are emitted by the plant, but there appears to be no difference in the actual blend of odours that is emitted. This will have consequences for the natural enemies that use plant odours as cues to locate their prey. The odours do not seem to provide much information on the identity of herbivores. This is

reflected in the above field experiments. Although the effects were sometimes marginal, the odours emitted by treated plants affected the attraction and distribution of a variety of natural enemies of herbivores. The studies of the effects of maize odours on the aphids revealed that in general healthy maize plants are attractive to them, but that induced odour emissions repel aphids. The particular aphid tested does not induce odour emissions, it is

therefore unlikely that it is repelled by the odour to avoid intraspecific competition. The complexity of the interactions is reflected in the results of the tests with two aphid species and two maize varieties. The two species responded differentially to the varieties. These results indicate that selecting the appropriate crop variety may influence the settling of aphids in the field and, therefore, decrease infestation rates in crop cultures.

Restoration of species rich meadows on formerly intensively used farmlands. A contribution towards the ecological improvement of cultural landscapes and the understanding of mesic grassland ecosystems

Renaturierung artenreicher Wiesen auf nährstoffreichen Böden. Ein Beitrag zur Optimierung der ökologischen Aufwertung der Kulturlandschaft und zum Verständnis mesischer Wiesen-Ökosysteme; 194 pp.

ANDREAS BOSSHARD

1 Since 1993, when the "Öko-Beitragsverordnung" decree was introduced in Switzerland, tens of thousands of hectares of intensively used agricultural land have been registered each year as "ecological compensation areas" which are financially supported by the federal government. The goal of the decree is to increase the ecological and aesthetic value of the landscape. Most of the areas registered have since been used as "extensively" or "less intensively managed meadows"; such areas represent some 85,000 ha or 8% of the agriculturally cultivated area of Switzerland. More than half of these meadows do not reach a satisfactory quality in ecological and aesthetic terms. How far and by what means can ecological improvement be achieved?

2 In this study, methods were developed for the restoration of species-rich grasslands on nutrient-rich soils. The data are based on 26 fields with c. 500 plots on more than 20 ha in the eastern Swiss Midlands, which were evaluated for 3–8 years. The evaluation of the

established grassland types is based on historically and ecologically determined principles (Leitbild). The results led to the recommendation of five relatively cheap seed mixtures to be used with a series of particular cultivation methods. A key is provided to determine the most appropriate method depending on site conditions.

3 The results show that under almost all site conditions ecologically and aesthetically valuable, stable Arrhenatheretum and, in some cases, Mesobromion meadow types can be established. These meadow types are highly endangered, as in the last decades more than 99% of their former area has been destroyed, mainly by agricultural intensification. Thus, restoration of species-rich meadows of the types mentioned is crucial to achieve the goals of "ecological compensation" in the Swiss lowlands.

4 The theoretical part of the thesis deals with the relationship between canopy structure of grasslands and its stability and species diver-

sity. The presence or absence of dominant species creating unfavourable canopy light climates is detected as a key factor, which in mesic meadow ecosystems seems to be more relevant for species richness and stability than the nutritional status of the soil. The study reveals how some characteristic species of mesic, species-rich grasslands react to different canopy structures both morphologically and in terms of vigour. A practical consequence is the recommendation that restoration methods should focus on the establishment of rather open canopy structures more than on the presence of a particular species composition.

5 A second result was that in complex systems cause and effect relationships may have no general validity, but depend on the temporal and spatial context. Many examples are given for opposite effects of a factor according to site conditions or the state of the ecosystem. Therefore, the research requirement of statistical testing ("depth" of a study) has to be completed by an explicit context evaluation ("breadth" of a study). Proposals are made on how these complementary research approaches may improve the applicability of research results in ecology.

6 In the methodological part the following field methods have been developed and tested: (1) A new experimental approach of on-farm-research, leading to a maximum ex-

tension of experimental plots combined with minimal costs. Such an approach guarantees relevance to the needs and restrictions of agricultural practice. (2) A research concept in which four experimental types are combined in such a way that an iterative process between generation and testing of hypotheses could result, accelerating the obtaining of results and decreasing the financial needs. (3) An experimental design and analytical method called "border line comparison", allowing hypotheses to be tested without experimental replicates. (4) A three step vegetation relevé method particularly suitable for inhomogeneous vegetation stands and allowing a much broader analysis than conventional relevés. (5) A cost-effective and realistic *in-situ* method to determine the potentially active seed bank under field conditions. (6) Two new approaches to assess the results of the restoration trials: The first is the concept of "functional balance" of the species composition, complementing the common concepts of diversity and evenness by considering the functional relevance of each species in an ecosystem. The second is based on the concept of the phytometer and consists of a set of sensitive target species which are sown in every plot with the same quantity and composition; the establishment of these species is regarded as a direct standard to assess the suitability of the various restoration methods.

Vegetation development on ecologically restored ski runs above the timberline

Entwicklung der Vegetation auf standortgerecht renaturierten Skipisten oberhalb der Waldgrenze;
147 pp.

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1 Ecological restoration of machine-graded ski runs in the alpine vegetation belt was assessed in the short- and mid-term with demographic monitoring of population and vegeta-

tion development. The clusters of trial plots were installed in 1985–1986 and 1995–1996, respectively. Only native alpine plants (13 grasses, 4 legumes and 7 forbs) were used as

transplants. Safe-site conditions were provided in some plots or sub-plots with biodegradable wood-fiber mats. To improve the topsoil structure, some sub-plots were amended with a small supplement of garden soil.

2 The transplant survival rates exceeded 70%. The re-juvenation of mixed stands was clearly recognisable as many transplant species quickly and successfully reproduced by seed. The diversity of angiosperms increased within 12 years from the initial 8 to 29 species. This increase resulted from colonisation from the adjacent natural vegetation and partly also from the neighbouring restoration plots. The ongoing population processes in the re-introduced and spontaneously immigrated species demonstrate the importance of safe sites for a successful restoration. It seems that both local installation of grown plants and use of biodegradable mats are useful in this context.

3 Survival was good in most species; some populations reached also the onset of flowering within 1–2 years from restoration. *Lotus alpinus* even produced a new generation of plants from self-seeding in the third year after the transplant establishment.

4 Comparative studies of some reproductive parameters in selected transplant populations and their respective donor populations revealed that at least some differences may become non significant within a relative short time span. These relative fitness features apparently have an important diagnostic value for the assessment of restoration success; they also bring about important information on the performance of the same or closely related genotypes in their natural populations and in the restoration site.

5 Development of vegetation on un-restored ski run was more advanced on the N-slope of Jakobshorn than on the SW-slope. This difference is attributed to a considerable variation in local site conditions.

6 Based on the results of monitoring most of the studied transplant species can be recommended as suited to restoration above the timberline. It is emphasised that diverse plant groups should be represented in the restoration material to ensure the risk distribution. The concept of safety islands, i.e. a local installation of restored plots in small clusters could be realised in practice without any considerable difficulties; its advantages are indisputably greater than those of commercial "re-greening".

7 The last part of the thesis is formed by a database dealing with alpine plants. This database is regarded as an important information source for potential users of native plants as restoration material above the timberline.

