An Abstract of the Thesis of

Patrik M. Schonenberger for the degree of Master of Science in Horticulture presented on January 29, 1999. Title: Evaluation of Botanical Diversity in Oregon Vineyards.

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Carmo Candolfi-Vasconcelos

Three different ground cover management strategies were compared at the OSU research vineyard near Alpine, Oregon. Botanical diversity was actively increased in two diverse treatments. Another treatment was botanically uniform and contained creeping bentgrass (*Agrostis stolonifera*). The composition of the vineyard floor vegetation and grapevine performance as affected by the treatments was evaluated.

Shoot length and average leaf size of the grapevines were increased (> 30%) in treatments with more diverse ground covers, the main-shoot leaf area per vine was larger but the lateral-shoot leaf area was not affected. Photosynthesis and transpiration rates were not different among the treatments except for two measurements, which showed lower photosynthesis rates in the bentgrass treatment. The water use efficiency of photosynthesis tended to be higher for grapevine leaves in more diverse treatments except at veraison 1997. The leaf chlorophyll content

was higher in the more diverse treatments at bloom, but was similar in all treatments later in the season.

The juice soluble solids (Brix) at harvest were higher (4 %) in the diverse treatments, and in one of the two investigated years, fruit yield was also higher. Percent fruit set, titratable acidity, and pH were not affected by the treatments.

The experiment showed that the grapevines in botanically uniform ('grass') plots produced less vegetative growth and delayed fruit maturity, even with a lower crop load.

In addition to the experiment, four commercial vineyards in the Willamette Valley in Oregon were surveyed to establish a list and number of resident (weedy) plant species. At the scale of the whole vineyards, 9, 10, 11, and 13 plant species were observed. All four sites were grass dominated and five broadleaf plant species occurred in all four sites.

The data sets indicated that the number of plant species was not in all cases randomly distributed over the vineyard. The data showed a continuous trend to higher numbers of plant species from east to west in one vineyard. In another vineyard, the data showed a patch of lower numbers of plant species in a small part of the field. The data in the other two vineyards did not indicate patterns or trends.

Evaluation of Botanical Diversity in Oregon Vineyards

by

Patrik M. Schonenberger

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APPROVED:

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Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Patrik M. Schonenberger, Author

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Evaluation of Botanical Diversity in Oregon Vineyards

Chapter 1: Introduction

Soil and vegetation management in agricultural systems impact physical, chemical, and biological properties of the soil and as a consequence crop plant performance. Vineyard soils are often clean cultivated or herbicide-treated to prevent excessive competition for water and nutrients because the majority of vineyards is concentrated in the dry Mediterranean-type climate. However, many vineyards in cooler and moister areas are located on hillsides. These soils are frequently covered with resident vegetation or cover crops to reduce soil erosion and surface water runoff, to improve year-round trafficability, and to slow the soil compaction process and subsequent loss of pore space. Today, ground covers are recommended for all viticultural areas at least during the dormant season of the grapevines (Boller, 1992).

Many cover crop experiments in agro-ecosystems include a pure stand of plant species or two and three species mixtures. Yield gain is unlikely to increase beyond three species (Swift and Anderson, 1994). In vineyards of the cooler areas like the Willamette Valley in Oregon, grape clusters are often removed during the season to reduce crop load and enhance fruit maturity (Lombard, 1992). The primary concern in these areas is improving fruit quality rather than increasing fruit yield. Research on multiple benefits of cover crop plants such as improving soil structure and water infiltration, protection of the soil from water and wind erosion, adding organic matter or nitrogen, suppressing weeds, attracting beneficial insects (Ingels *et al.*, 1994) recommend using plant mixtures with more than three species.

The composition of the plant community is a key element in agro-ecosystems (Fox, 1991a; Fox, 1991b; Ingels *et al.*, 1994). High botanical diversity is positively related to high faunistic diversity (Remund *et al.*, 1989; 1992) and the number of sudden and damaging pest outbreaks may decrease significantly in very diverse agro-ecosystems (Altieri, 1994; Remund *et al.*, 1989). The survival of predatory arthropods depends in many cases on alternate food supply (pollen, nectar) during times of low prey density (Engel and Ohnesorg, 1994b; Wiedmer and Boller, 1990). A rich mixture of plants that are flowering at different times during the season provides a dependable food supply and a favorable habitat, promoting natural control of grapevine pests (Remund *et al.*, 1992). The general link between diversity and ecological stability is still a subject of debate and it is argued that precise descriptions of the diversity-stability relationship demand long-term studies under changing weather conditions (Woodward, 1994). Vitousek and Hooper (1994) proposed to initiate experiments with levels of diversity applied as treatments.

In modern viticulture, physical soil properties are more often growth limiting than chemical soil properties which are generally optimized with available management input (Hess, 1994). In seven vineyards in Switzerland, decreasing soil aggregate stability was responsible for limited growth of feeder roots and, as a consequence, reduced canopy growth (Hess and Oertli, 1991). Cover cropping, liming, adding organic matter, or introducing a fallow period after breaking up the soil were proposed to solve the problem in the vineyards studied (Hess and Oertli, 1991).

The objective of the present study was to contrast grapevine performance in plots with lower versus higher botanical diversity in a typical vineyard in Oregon. Vineyards in Oregon are typically planted into grassland on heavy soils with low pH (Connelly *et al.*, 1993). Most precipitation falls throughout the winter and spring whereas summers are generally dry (Oregon Climate Service, average 1961 to 1990). A botanical survey in commercial vineyards was carried out in addition to the experiment to establish a list of resident (weedy) plant species in Willamette Valley vineyards in Oregon. The two scales of interest were the space surrounding each single grapevine and the entire vineyard.

Chapter 2: Literature Review

Pioneering work of the IOBC (International Organization for Biological and Integrated Control of Noxious Animals and Plants) put integrated pest management (IPM) into the broader frame of integrated production (IP). The concept of IP is open and dynamic, and the broader context may further improve management decisions and management practices in the agro-ecosystem (Boller, 1992). Agro-ecologists and information analysts explored the importance of a wider frame beyond IPM. IP was promoted to direct the focus towards the management of entire agro-ecosystems instead of solving single problems with single solutions within the systems (Boller *et al.*, 1990; Bugg and Van Horn, 1998; Edson *et al.*, 1996; Hanna *et al.*, 1996; Hofmann *et al.*, 1994).

The ecological diversification of the vineyards is important in that broader frame (IOBC, 1993; IOBC, 1996) because diversified vineyards are better able to buffer sudden increases of pest populations (Boller, 1992). The first practical step to transform conventionally managed vineyards into IP vineyards is managing the vegetation to increase botanical diversity rather than botanical uniformity, and to evaluate grapevine performance (vigor, fruit yield and quality). Growers are encouraged to initiate and carry out small-scale experiments to test research information on individual sites (Basler, 1990).

Practical view of the agro-ecosystem 'vineyard'

Agro-ecosystems are clearly distinct from natural ecosystems in their function to produce a harvestable yield (Swift and Anderson, 1994). Harvestable yields in the context of integrated production are rather optimized than maximized, with a general emphasis on high fruit quality and long-term viability by minimizing disturbing management practices and using existing natural regulatory mechanisms in the field (Boller, 1992; IOBC, 1993).

Several different approaches were taken to describe a simplified and practical view of a vineyard to facilitate concrete management decisions. Boller (1988) used a dual-frame diagram with the vineyard floor vegetation and the grapevines in the center of the inner frame, surrounded by regionally important pests, diseases, predators, and indifferent organisms (Figure 2.1.). The inner frame includes basically all living organisms in the vineyard. A second larger frame encloses the inner frame and adds cultural practices and other management input to the system. The most significant positive or negative interactions among the components are shown. The model is considered to be a working tool for growers and researchers in a specific region.

In a second approach, Hanna *et al.* (1996) isolated one component of a vineyard (cover crop) and linked it to other affected components that can be studied simultaneously. The study gradually expanded, more sites were added and the

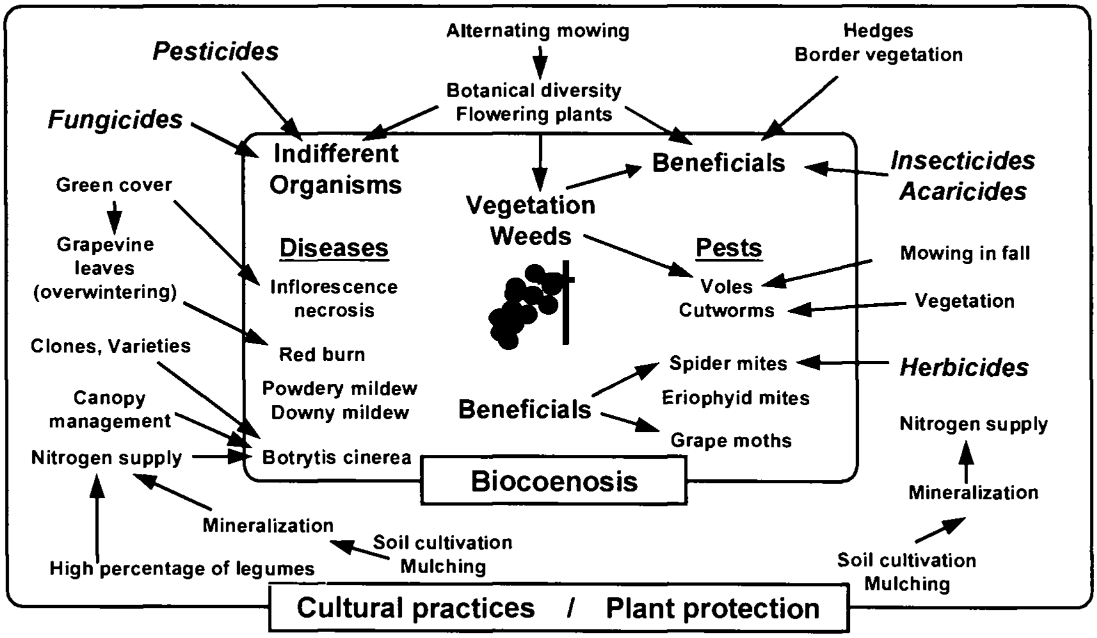

Figure 2.1. Practical view of a typical vineyard-ecosystem in Eastern Switzerland. Arrows indicate the most significant internal and external influences on individual components of the system. Only major pests and diseases are displayed in this diagram for its applicability in the field. (Reproduced from Boller, 1988, with permission E.F. Boller).

expertise of additional scientists was included in the multidisciplinary research team.

Finally, Bugg and Van Horn (1998) comprehensively analyzed the existing literature related to a set of management concepts for one vineyard component and discussed practical knowledge that influenced management decisions in the field.

In order to combine and to generalize the three approaches (Boller, 1988; Hanna *et al.*, 1996; Bugg and Van Horn, 1998), a modified older version of the IP model (Boller, 1983; Boller and Remund, 1986) is shown in Figure 2.2. This version could be more practical for Oregon vineyards that are not well characterized yet. The grape grower and grapevines are placed in the center. The list to the left side shows components and observations of the vineyard. The list to the right includes sets of management concepts. Motivation and continuing education lead to improved management practices to balance vine vigor, fruit yield

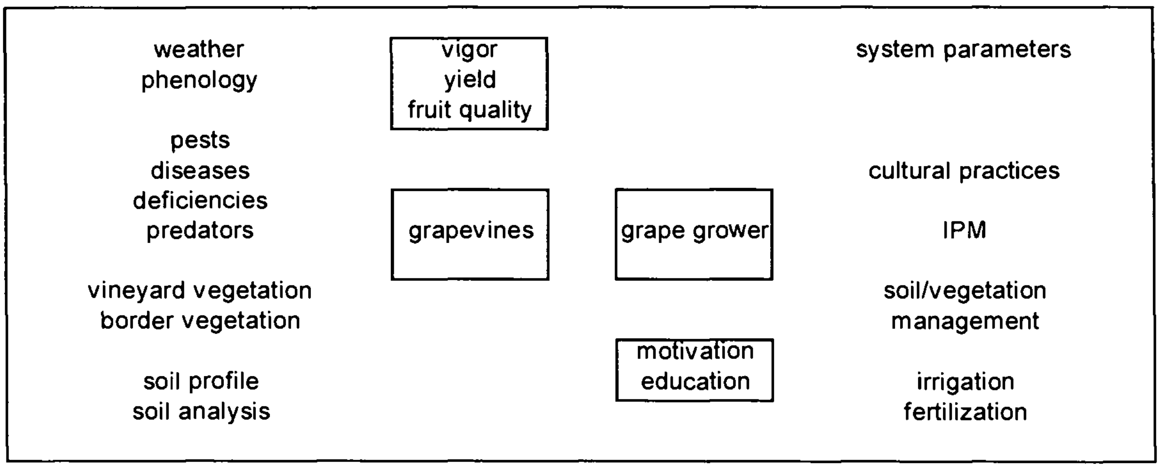

Figure 2.2. Practical view of the agro-ecosystem 'vineyard' with the interaction of the grape grower and the grapevines placed in the center. The list to the left shows the most important practical components and observations from the vineyard. The list to the right includes sets of management concepts. (Modified from Boller, 1983; Boller and Remund, 1986).

and quality. Educated decisions concerning system parameters is given first priority in the frame of integrated pest management and integrated production in viticulture (Boller and Basler, 1987). Decisions made before planting, such as site selection, choice of plant material and rootstocks define the system parameters (Boller and Remund, 1986). Cultural practices in a vineyard include pruning, canopy management, fruit thinning, plant protection, fertilization, irrigation, and the choice of the trellis system (Boller, 1983). IP emphasizes moderate shoot and leaf density for optimal light and moisture environment within the canopy (Candolfi-Vasconcelos, 1995). Soil and vegetation management practices (including irrigation and fertilization) need to be adapted and synchronized with the grapevine phenology to take advantage of existing natural resources and to minimize management inputs (Perret *et al.*, 1989, 1991, 1994).

Botanical diversity in the agro-ecosystem 'vineyard'

On a global scale, species diversity decreases towards the poles and towards drier climatic areas (Woodward, 1994). In agro-ecosystems, species diversity often decreases because fairly intensive management practices are applied. Researchers do not agree whether uniformity is more efficient than diversity, biologically or economically (Swift and Anderson, 1994). It was suggested to apply levels of diversity as experimental treatments, especially in the range from one to ten species (Vitousek and Hooper, 1994).

Entomologists were the first ones to promote botanical diversity in managed ecosystems because case studies indicated that the number of sudden and damaging pest outbreaks decreased significantly in very diverse systems (Altieri, 1994; Remund *et al.*, 1989). A continual supply of flowering plants in a vineyard can assure the presence of important beneficial arthropods during the season (Boller, 1992; Remund *et al.*, 1989; 1992). Extensive research was carried out with the most important predatory mite (*Typhlodromus pyri*) in cool climate viticulture. *Typhlodromus pyri* survived and reproduced in laboratory studies when fed with pollen of several weeds that are common in Eastern Switzerland vineyards (Boller and Frey, 1990). In vineyards with low pest mite populations, *Typhlodromus pyri* remained active and observations showed increasing numbers of predatory mites with increasing densities of windblown weed pollen on grapevine leaves (Wiedmer and Boller, 1990). These results correspond with results of comprehensive investigations with *Typhlodromus pyri* in the laboratory and in vineyards in Germany (Engel and Ohnesorge, 1994a; 1994b).

On the other hand, agro-ecosystems may function efficiently and maintain biological stability at quite low numbers of plant species (Swift and Anderson, 1994). It was hypothesized that the maximum efficiency in an agro-ecosystem is reached when its plant subsystem assumes dominant control over its decomposer subsystem (Swift and Anderson, 1994), i. e. permanent presence of plants for continuous nutrient cycling between the plant subsystem and the decomposer subsystem. The specific composition of the plant community seems to be of prime importance. Combining the resident vegetation with commercially available plants (low seeding rates) that have desired functional attributes is recommended for a managed diverse plant community (Fox and Straub, 1993). Such attributes should effectively assist management inputs or replace management tools. Desirable plant attributes include attracting beneficial arthropods (Remund *et al.*, 1989; 1992), fixing atmospheric nitrogen (*Fabaceae*), growing rapidly and maturing early in spring (*Poa annua*, *Stellaria media*, *Veronica sp.*, Perret and Koblet, 1973), or the ability to expand the root system in poorly aerated soils (*Raphanus sp.*, Perret, 1982). It may take several years to diversify the plant community, to transform and manage the vegetation from a low number of plant species to a high number of plant species inside and around a vineyard. Less intensive soil and vegetation management practices did result in a higher level of botanical diversity in trials in Switzerland (Gut *et al.*, 1995). For vineyards, such practices addressed the timing of the first mowing (or cultivating) in the season (Gut *et al.*, 1995), the mowing frequency during the season (Gut *et al.*, 1995), the cutting height of the vegetation (Bugg and Van Horn, 1998), fertilizer rates (especially nitrogen) for each specific site and block within a site (Fox and Straub, 1993), and the frequency of herbicide use (IOBC, 1996).

Evaluation of the ground cover in orchards and vineyards

Boller (1990) refers to the vineyard (and orchard) ground cover as an ecological 'turn-table' that activates and influences a series of other key components. In cool climate sites, ground covers are widely used where precipitation exceeds 600-700 mm per year. Comprehensively evaluating floor vegetation and management strategies is difficult because of the great complexity of interactions between physical, chemical, and biological soil properties. Hogue and Neilson (1987) reviewed 200 studies concerning four major vegetation management systems in orchards. The four systems examined were permanent ground cover, mulching, cultivation, and use of herbicides. Effects of these management systems on trees (vigor, leaf nutrient content, and root development), on fruit crops (yield, nutrient content, and quality of the fruit), and on several soil properties (organic matter, nutrients, pH, moisture, other soil physical properties, and temperature) are discussed. They remarked that a complete evaluation should include effects on vole and other pest populations, pest management, orchard temperature, and allelopathy. Also comparative economic costs should be considered. In most of the reviewed studies, a permanent ground cover between the rows (sod, sward, or grass) was used as the standard or control treatment. However, vegetation management practices in vineyards are often compared with clean cultivated or herbicide-treated plots. This is especially true for research carried out in areas with little rain during the growing season or in vineyards with high planting densities (Dorigoni *et al.*, 1991; Lombard *et al.*, 1988; Maigre, 1998; Saayman and Van Huyssteen, 1983; Wolpert *et al.*, 1993).

Hess and Oertli (1991) concluded from data collected in seven vineyards in Switzerland that the major factor for reduced grapevine canopy growth was restricted root growth, caused by decreased soil aggregate stability. Dependent and independent soil properties, (low organic matter content, low pH, increased heavy metal concentration, loss of pore space, methane or ethylene produced by anaerobe microorganisms) that might be responsible for the loss of aggregate stability were summarized. Liming, adding organic matter and cover cropping after deep cultivation were proposed to solve the problems in the vineyards.

Parameters to evaluate the physiological development of grapevines in the field include observations that express their vigor, fruit yield and fruit quality. Leaf gas-exchange measurements, CO_2 gain and transpirational H_2O loss through the stomata, were conducted in applied plant physiological studies to calculate the instantaneous water use efficiency of photosynthesis at selected phenological growth stages of the grapevines (Maigre, 1996; Wolpert *et al.*, 1993). Climatic conditions, leaf development, leaf age, and stress situations affect the water use efficiency of photosynthesis at the scale of the whole plant (Larcher, 1995).

Rodents are abundant in diverse plant communities. Their eating preferences may change the plant composition. Rodents sometimes feed on crop plants, but they are rarely attracted to roots of mature grapevines (>3 years old) if other sources of food, like fleshy roots of ground cover plants, are available (Meylan, 1981). During a four-year study with voles (*Arvicola terrestris*), Saucy (1988) observed that rodent immigration into a new field depended primarily on vegetation and stand density. He remarked that short floor vegetation during the time of immigration could be of prime importance to prevent high rodent population density in a field.

Ground covers with gramineous plant species only

Many vineyards in the Willamette Valley are planted on south facing hillsides (Connelly *et al.*, 1993). South facing hillsides in Western Oregon are described as grasslands, prehistorically created by fire and later maintained by a combination of grazing and fire (British Columbia Forest Service, 1994). Additionally, recently logged, disturbed habitats often contain, beside the grasses and few other weed species, wild blackberries (*Rubus discolor*, *Rubus laciniatus*) and scotch broom (*Cytisus scoparius*) (British Columbia Forest Service, 1994). General recommendations for year-round weed management strategies in Oregon vineyards are aimed at combining a variety of management practices: including occasional tillage, frequent mowing or flailing, selective application of herbicides, and planting ground covers (William, 1992). Grass covers are often preferred over more diverse ground covers because several attributes make gramineous plants the logical choice for vineyards. Such attributes are competitive abilities to reduce vegetative growth of the grapevines in very vigorous sites, smooth surface for easy vineyard accessibility, little or no rodent infestation, and easy establishment because some grass species are resident and well adapted to most vineyard sites.

Kreimeyer (1992) discussed establishment, management, advantages, and disadvantages of grass covers. He noted that a decision still needed to be made weighing advantages and disadvantages for each individual site. Mixes of grasses might perform better than pure stands of a single grass species (William, 1992).

William (1989) reviewed the research addressing the use of perennial turfgrasses in horticultural crops in Western Oregon. Most studies conducted in vineyards compared treatments with pure stands of grass species and evaluated water use, nitrogen use, or grapevine response.

Promising grass cultivars were tested under Oregon conditions to give the industry more and better choices of grass species that could be used as ground covers in vineyards and other horticultural crops. In a small plot study, 15 grass cover crops were visually scored concerning grass vigor, stand density, trafficability, and rodent activity (Stannard *et al.*, 1997). The authors summarized the performance of each grass. Doty *et al.* (1990) compared evaporation of bare ground with evapotranspiration of three cultivars of perennial ryegrass (*Lolium perenne*), one cultivar of tall fescue (*Festuca arundinaceae*) and one cultivar of colonial bentgrass (*Agrostis tenuis*) over three years in non-irrigated plots. The grasses used significantly more water than the bare ground treatment, but no differences in evapotranspiration among grass cultivars were detected. Lombard *et al.* (1988) used perennial ryegrass in a non-irrigated vineyard and compared it to bare ground plots. The effects on vine growth, fruit yield and composition were evaluated. The grapevines in the grass plots had reduced vegetative growth and fruit yield, but the fruit composition was not different compared to the fruit in the bare ground plots. Additionally, the grapevines developed fewer roots below the ryegrass strips compared to open soil (no grass). Tan and Crabtree (1990) studied the effects of mowed and unmowed perennial ryegrass (*Lolium perenne*), and bare vineyard floor, in combination with three levels of nitrogen fertilization, on mineral nutrient concentrations in grapevine leaves. Compared to bare soil, the grass significantly lowered nitrogen concentration in the leaves of the grapevines. Only very high rates of urea (274 kg N/ha) eliminated the differences in leaf nitrogen concentrations among the treatments. In addition, the grass reduced Fe, S, Ca, B, and Mn concentrations in one of the two study years. Wilson (1985) investigated the response of 'Pinot noir' grapevines to a ryegrass cover crop with and without irrigation. Grapevine response in the ryegrass plot was not different from the control (open soil) treatment, but irrigation increased shoot growth and pruning weight and delayed fruit maturation in both treatments. A study in California tested the hypothesis, whether 'Berber' orchardgrass compared to clean cultivated plots would be able to reduce grapevine shoot growth, improve canopy light exposure, microclimate, and as a consequence improve bud fruitfulness and increase fruit yield (Wolpert *et al.*, 1993). In their experiment, reduced shoot growth was accompanied by reduced yield. Dorigoni *et al.* (1991) observed similar grapevine responses in a three-year experiment in Northern Italy. Clean cultivated, herbicide-treated, tall fescue (*Festuca arundinacea*), and annual ryegrass (*Lolium multiflorum*) plots were compared. The study showed that contrasting weather conditions (dry versus wet) over the investigated years had a much greater (100 fold) impact on grapevine performance than single year comparisons of the applied treatments.

Ground covers with gramineous and broadleaf plant species

More recent interest in integrated pest management and integrated production led to the discussion of additional benefits of cover crop plants and the possibility of using rich mixtures of plants or the resident vegetation in vineyards (Boller and Remund, 1986; Bugg and Van Horn, 1998; Fox, 1991a; Fox, 1991b; Fox and Straub, 1993; Hanna *et al.*, 1996; Hofmann *et al.*, 1995; Remund *et al.*, 1989; 1992). Interactions between cover crop plants and other components in the agro-ecosystem are still poorly understood because of the complexity of the field conditions. Research effort was placed on establishment and basic management strategies for plant mixtures in changing environmental situations (Fox and Straub, 1993; Hofmann *et al.*, 1995). Site characteristics and local weather patterns determine whether a plant mixture establishes (Fox, 1991a; Fox, 1991b). Extensive research with several cover crop plants, plant mixtures, and the resident vegetation was carried out in vineyards in Switzerland (Perret and Koblet, 1973; Perret, 1982; Perret *et al.,* 1989, 1991, 1994). The early experiments focused on establishment of the cover crops and their effects on grapevine performance (fruit yield and quality).

Adaptive nitrogen management was developed in the more recent studies: the resident vegetation was managed to synchronize nitrogen availability in the soil with the nitrogen demand of the grapevines (Perret *et al.,* 1989, 1991, 1994). The grapevines have a high nitrogen demand from prebloom until the beginning of ripening (veraison).

In a study in California, soil structure and cumulative water infiltration into the soil were improved in five treatment plots with vetch, clover, bromegrass, a vetch-oat mixture, and the resident vegetation compared to plots with no cover (Folorunso *et al.*, 1992). Improved soil physical properties, but decreased grapevine shoot growth and lower fruit yield, was observed in a study in South Africa after winter clover (*Medicago trancatula*) was applied to a treatment plot (Saayman and Van Huysteen, 1983). Over the time of the study, grass (*Bromus wildenowii*) invaded the winter clover plots and the authors concluded that competition for nitrogen and moisture was the main cause for decreased grapevine performance. Exact timing of soil and vegetation management practices may improve soil physical properties (Saayman and Van Huyssteen, 1983) and grapevine performance in vineyards (Perret *et al.*, 1994).

Spatial distribution of botanical diversity in managed ecosystems

Plants in natural or managed diverse ecosystems often grow in patches. Spatial dependence of vegetation distribution is more practical and realistic than spatial independence (Rossi *et al.*, 1992). The sampling design determines the scale at which patches are detectable. Many botanical field studies describe the composition of plant communities by surveying and extrapolating small representative parts of a larger field because the vegetation was either fairly uniform or the patterns were assumed to repeat over the entire study area. Remund *et al.* (1989) surveyed two vineyard sites in Eastern Switzerland with different vegetation management. One site (0.04 hectares) was tilled in the spring and mowed twice later in the season. The other site (1.66 hectares) was mowed twice. Two rectangular areas (12 m^2) were sampled in both sites. Plants were counted weekly from May through July. The tilled site had 25 plant species and the mowed site 95. Fardossi *et al.* (1996) sampled a small, representative area (30 m^2) in a vineyard during a fallow period of approximately eight months and found a total of 46 plant species from 22 plant families. Navas and Goulard (1991) analyzed the spatial distribution of the single most abundant weed (*Rubia peregrina*) in a herbicide treated vineyard northwest of Montpellier, France. Four small rectangular plots (each 2.5 m^2) were sampled twice (April and January). Beside *Rubia peregrina*, six other weed species were identified. Mahdi and Law (1987) surveyed one hectare of limestone grassland in Derbyshire, UK, with a history of infrequent fertilization and rough grazing by cattle and rabbits for 60 years. An area (40 m^2) of visually homogeneous vegetation was selected and subsampled. Fifty-seven flowering plant species were present of which 36 species occurred in the subsamples that were taken during the last week of July. In a study that was carried out near Dijon, France, Dessaint *et al.* (1991) sampled soil cores to count weed seeds in 75 m^2 of a 1.16-hectare field. The field was cropped with spring peas in 1985, winter wheat in 1986, and winter barley in 1987. The seed-bank flora consisted of 31 plant species.

Levin (1992) emphasized choosing the scale of a study from the processes that form the pattern rather than from the visible pattern themselves. If management practices mask underlying processes, management is the dominant process and a survey should extend over the entire managed field or plot. This approach was taken in some studies. Elmore *et al.* (1989) surveyed plant diversity in a study in two almond orchards in California. Rings, 20 cm diameter, were randomly thrown within each plot and the presence (or absence) of a plant species was recorded. In the treatment with resident vegetation 3 to 9 (orchard A) and 9 to 13 (orchard B) plant species, respectively, were counted in the April surveys during the five-year study. Holt *et al.* (1995) experimentally fragmented a 12-hectare field in Kansas, USA. Historically a tallgrass prairie and oak-hickory forest, the field was farmed until 1970, left fallow until 1980 when it was farmed again. In 1984, the field was mowed and disked and left undisturbed for data collection each spring and fall for six years. The size of the sample plots were 32, 288, and 5000 m^2. Annual counts of plants from subsamples showed ranges from 60 to 94 species in the small plots, 60 to 82 species in the medium plots, and 77 to 103 species in the large plots.

These examples demonstrate the large differences in the way spatial and temporal scales are used in vegetation surveys. Comparing observations among fields becomes difficult. Rossi *et al.* (1992) offered a comprehensive and practical introduction for the use of geostatistical tools to analyze and interpret ecological spatial dependence. Turner *et al.* (1991) summarized 13 quantitative methods to describe and analyze biodiversity or vegetation patterns at the landscape level. These techniques may also be used for the analysis of vegetation patterns in agricultural ecosystems (J.A. Jones, Dept. of Geosciences, OSU, personal communication, 1997) in which management is often the dominant process that form the observed patterns of the plant communities (Elmore, 1989; Gut *et al.*, 1995; Remund *et al.*, 1989).

Chapter 3: Effects of Weed Management Practices on Vineyard Vegetation and Grapevine Performance

Abstract

Three different ground cover management strategies were compared at the OSU research vineyard in Alpine, Oregon. Botanical diversity was actively increased in two treatments. One treatment was botanically uniform. The composition of the vineyard floor vegetation and grapevine performance as affected by the treatments was evaluated.

In the spring surveys, the more uniform treatment (>95% gramineous plants) contained two to four flowering plant species at the scale of the plots. The two more diverse treatments contained six to eight flowering plant species at the same scale. The relative abundance of gramineous plants in the more diverse treatments was 45% and 48%, respectively, in 1996, 80% and 70%, respectively, in 1997.

Shoot length and average leaf size of the grapevines were increased (>30%) in treatments with more diverse ground covers, the main-shoot leaf area per vine was larger but the lateral-shoot leaf area per vine was not affected. Photosynthesis and transpiration rates were not different among the treatments except for two measurement dates with lower photosynthesis rates in the 'grass' treatment. The

water use efficiency of photosynthesis tended to be higher for grapevine leaves in the more diverse treatments except at veraison of 1997. The leaf chlorophyll content was higher in the more diverse treatments at bloom. These differences were not significant later in the season.

Fruit set was not affected by the treatments. In both investigated years, the soluble solids (Brix) at harvest were higher (4%) in the more diverse treatments and in the second year, the grapevines produced higher fruit yield in the more diverse treatments. Other crop parameters were not different among the treatments.

The experiment showed that the grapevines in botanically uniform ('grass') plots produced less vegetative growth and delayed fruit maturity, even with a lower crop load.

Introduction

Integrated production in viticulture promotes stabilization of the agro-ecosystem by increasing and maintaining biological diversity inside and around the vineyard (Boller, 1992; IOBC, 1996). A crucial step in the context of integrated production is managing the floor vegetation to increase botanical diversity rather than botanical uniformity because diversified vineyards are better able to buffer sudden increase of pest populations (Boller, 1992). Entomologists linked high botanical diversity with high faunistic diversity (Altieri, 1994; Remund *et al.*, 1992), and case studies in vineyards showed that high faunistic diversity significantly decreased the number of sudden and damaging pest outbreaks (Remund *et al.*, 1989). On the other hand, agro-ecosystems may function efficiently and maintain biological stability at relatively low numbers of plant species (Swift and Anderson, 1994), namely when a plant community assumes dominant control over its decomposer subsystem (Swift and Anderson, 1994) i.e. permanent presence of plants for continuous nutrient cycling between the plant subsystem and the decomposer subsystem. It was suggested to initiate experiments with levels of diversity applied as treatments (Vitousek and Hooper, 1994).

Combining the resident vegetation with commercially available plants (low seeding rates) that have desired attributes is recommended for a diverse plant community (Fox and Straub, 1993). These attributes should effectively assist management input or replace management tools, e.g. attracting beneficial arthropods (Remund *et al.*, 1989; 1992), fixing atmospheric nitrogen (*Fabaceae*), growing rapidly and maturing early in spring (Perret and Koblet, 1973), or the ability to expand the root system in poorly aerated soils (*Raphanus sp.*, Perret, 1982).

Less intensive management practices increased botanical diversity in case studies in Switzerland (Gut *et al.*, 1995). Such practices addressed the timing of the first mowing (or cultivating) in the season (Gut *et al.*, 1995), mowing frequency during the season (Gut *et al.*, 1995), cutting height of the vegetation, fertilizer rates (especially nitrogen) for each specific site and block within a site (Fox and Straub, 1993), and the frequency of herbicide use (IOBC, 1996).

Vineyards in Oregon are predominantly planted on grassland (Connelly *et al.*, 1993). Until recently, the recommendations for vineyard floor management strategies focused on sod cultures (grass covered ground) that were frequently mowed or flailed, combined with occasional tillage, and selective application of herbicides (Kreimeyer, 1992; William, 1992). The result was often a dense grass monoculture with possibly limited grapevine feeder roots (Lombard *et al.*, 1988). Grapevine efficiency could decrease with decreased growth of feeder roots (Hess and Oertli, 1991; Hess, 1994). Most experiments conducted in Oregon vineyards tested grass varieties or compared pure stands of grass species with bare soil treatments and evaluated water use, nutrient use, or grapevine response (Doty *et al.*, 1990; Lombard *et al.*, 1988; Stannard *et al.*, 1997; Tan and Crabtree, 1990; Wilson, 1985).

The objective of this study was to actively increase botanical diversity in two treatments and to contrast grapevine performance in plots with different levels of botanical diversity. The number of flowering plant species and the relative abundance of gramineous and broadleaf plants were used to determine the levels of botanical diversity.

Materials and Methods

Study site and treatments

The experiment was initiated in the spring of 1995 at the OSU Woodhall III Vineyard near Alpine, Oregon. The region has an average annual precipitation of 108 cm (Oregon Climate Service, average 1961 to 1990). Most of the rain falls from October through June. The summer months are dry. The selected vineyard is southern exposed on a well drained, red soil that contains 27 - 40 % clay with an acidic pH (< 6.0). The soil is a member of the Jory-Bellpine association, with sandstone as the underlying bedrock. The experimental plot consisted of 17-year old, own-rooted 'Pinot noir' grapevines (clone UCD 22) that are spaced 1.8 m within the rows and 2.7 m between the rows. Grapevines are trained to the Guyot trellis system with two canes of 6-12 nodes each per vine, depending on vine vigor. Trunk height is 0.8 m. During the 1996 and 1997 seasons, grapevine canopies in all treatment plots were managed according to the principles and guidelines of integrated production in viticulture (Candolfi-Vasconcelos, 1995). Emphasis was put on moderate shoot and leaf density for optimal light and moisture environment within the canopy.

Prior to this study, a dense stand of creeping bentgrass (*Agrostis stolonifera*) dominated the entire research plot for several years. This existing and almost uniform plant community was compared and contrasted to two more diverse plant communities: one diverse treatment (referred to as 'resident') had a variety of resident plant species, particularly broadleaf species, that emerged naturally beside *Agrostis stolonifera* after cultivation in spring 1995. The other diverse treatment (referred to as 'seed') had a commercial seed mixture (low growing insectary plant mixture, Peaceful Valley Farm Supply Inc., Grass Valley, California) sown after cultivation, also in spring 1995. The seed mixture included ten low growing plants from the parsley (*Apiaceae*), mustard (*Brassicaceae*), and legume (*Fabaceae*) families. The plants were alyssum (*Alyssum sp.*), carrot (*Daucus sp.*), chervil (*Anthriscus sp.*), coriander (*Coriandrum sp.*), crimson clover (*Trifolium incarnatum*), nasturtium (*Nasturtium sp.*), parsley (*Petroselinum sp.*), subterranean clover (*Trifolium subterraneum*), white clover (*Trifolium repens*), and yarrow (*Achillea millefolium*). Each treatment was applied to the in-row and the row-middles to attain 100% cover. The replicates were two adjacent row-middles (plot size: 5.5 m x 48 m) and contained 26 grapevines. Five vines per replicate were randomly chosen and used for data collection at four phenological growth stages (bloom, fruit set, veraison, and fruit ripeness). Guard rows separated the plots. No data were collected from vines in the guard rows. The plant communities were established during the first season (1995). In the 1996 and 1997 seasons, all plots were alternately mowed: i.e. the first time (mid May), only every other row-middle was mowed, the second time (late June), all remaining row-middles, and the third time (late July), the entire plot. The in-row (under the vines) was mowed each time (mid May, late June, late July). No irrigation water or fertilizer was applied to any of the plots during the two years of the study.

Initially, the study included two similar sites. The experiment at the second site was discontinued because of 100% frost damage in May 1996.

Plant composition of the vineyard floor

The plant composition of the vineyard floor was surveyed by identifying and counting flowering plants in the plots along 5.5 m transects. One day before mowing, three samples per replicate were taken each time. Transects were randomly placed but laid out parallel to the row orientation. Plants at the flowering stage on the transects were counted and identified. The total number of plants in the floor vegetation and the relative abundance of gramineous and broadleaf plant species were recorded.

Vegetative growth

Shoot length and shoot diameter was measured at bloom before the first hedging. One shoot of each data vine was collected at harvest, and the leaf areas of main and lateral shoots were measured with a leaf area-meter model LI-3100 from Li-cor (Li-cor Inc., Lincoln, Nebraska, USA).

Leaf gas-exchange and chlorophyll content

Measurements were conducted three times at three phenological stages (bloom, fruit set, and veraison) on the tenth main-shoot leaf (from the base) from one shoot per data vine (five vines per replicate). The day before the measurements were done, the sampled leaves had been checked to ensure that they were fully exposed to the morning sunlight. Readings were taken with a portable infrared gas analyzer (Ciras-1, PP SYSTEMS, Hitchin, Herts SG5 1RT, UK) between 9:00 a.m. and 12:00 noon at photosynthetic flux densities above 1200 $\mu mol.m^{-2} s^{-1}$. During the measurement period, the air temperature ranged between 26 and 31 C. The instantaneous CO_2 gain and transpirational H_2O loss through the stomata were used to calculate the water use efficiency of photosynthesis.

In 1997, a portable leaf greenness meter (Spad-502, Minolta) was used to assess the chlorophyll content on the same leaves that were sampled for gas-exchange. The Spad-502 measures the light absorbency of the leaf at two wavelengths (red and near-infrared region) and calculates a numerical value that is closely related to the chlorophyll content in the leaf (Candolfi-Vasconcelos *et al.*, 1994).

Fruit set

Prior to bloom, five inflorescence clusters per replicate were enclosed into pollination bags to retain all shed flowers. The bags were removed at the end of July and all the abscised flowers were counted. At harvest, these clusters were picked, berries were counted and the number of flowers per cluster was calculated as the sum of shed flowers and berries. Percent fruit set was calculated as the ratio of berries per cluster at harvest and the total number of flowers per inflorescence.

Fruit yield and composition

Data vines were harvested individually to determine yield per vine. In addition, the spacing of the grapevines and the number of shoots per vine were used to calculate yield per unit of surface and yield per shoot. Samples of 12 grape clusters per vine were crushed to analyze juice soluble solids (Brix), titratable acidity and pH. Cluster weight was calculated by averaging the weight of the 12-cluster sample. Standard procedures were used for the juice analysis.

Statistical analysis of grapevine performance

Data were analyzed by ANOVA, using a generalized linear model procedure (SAS Institute, N.C. 1990). In addition, a set of orthogonal contrasts was constructed. The means of the 'grass' treatment (lower botanical diversity) were compared with the means of the 'resident plant' and 'seed mixture' treatments (higher botanical diversity) in order to gain information on the difference between plots with contrasting levels of botanical diversity. The second contrast compared the means of the two more diverse treatments with each other. A repeated measures analysis was performed on the data to detect year effects.

Results

Plant composition of the vineyard floor

A list of flowering plant species and the relative abundance of gramineous and broadleaf plants at the scale of the whole treatment plots are presented in Table 3.1.

At prebloom 1996, the 'grass' treatment had one broadleaf plant species: Spotted cat's ear (*Hypochaeris radicata*). More than 95% were gramineous plants and less than 5% broadleaf plants (Table 3.1.). Four ('resident') and seven ('seed') broadleaf plant species, respectively, were counted in the more diverse treatments. The 'seed' treatment consisted of 48% gramineous plants and 52% broadleaf plants (Table 3.1.). Almost the same ratio was observed in the 'resident' treatment with 45% gramineous plants and 55% broadleaf plants (Table 3.1.). Dandelion

Table 3.1. Plant composition of the vineyard floor in the experimental plots. The total number of flowering plant species and the relative abundance of gramineous and broadleaf plants are shown for four different sampling dates (prebloom 1996 and 1997, fruit set 1997, and veraison 1997). The lower part of the table is a list of flowering plant species in the plots at each sampling day.

	prebloom 1996			prebloom 1997			fruit set 1997			veraison 1997		
treatment	grass	resident	seed	grass	resident	seed	grass	resident	seed	grass	resident	seed
total number of plant species at the scale of the plots	2	7	8	4	6	6	4	5	6	1	2	2
gramineous plants	>95%	45%	48%	>95%	80%	70%	>95%	80%	75%	>95%	85%	95%
Agrostis stolonifera	x	x	x	x	x	x	x	x	x	x	x	x
Lolium sp.	-	x	-	-	x	-	-	-	-	-	-	-
Poa annua	-	x	-	-	-	-	-	-	-	-	-	-
broadleaf plants	<5%	55%	52%	<5%	20%	30%	<5%	20%	25%	<5%	15%	5%
Achillea millefolium	-	-	x	-	-	x	-	-	-	-	-	-
Daucus carota	-	-	x	-	-	-	-	-	-	-	-	-
Geranium sp.	-	-	-	-	x	-	-	-	-	-	-	-
Hypochaeris radicata	x	x	x	-	x	x	x	x	x	-	x	x
Lotus micranthus	-	-	-	-	-	x	-	x	x	-	-	-
Myosotis laxa	-	-	-	x	-	-	-	-	-	-	-	-
Plantago lanceolata	-	-	-	x	-	-	-	-	-	-	-	-
Rumex acetosella	-	-	x	-	x	x	-	-	x	-	-	-
Senecio vulgaris	-	x	x	-	-	-	-	-	-	-	-	-
Sonchus sp.	-	x	x	-	-	-	x	x	x	-	-	-
Taraxacum officinalis	-	x	-	-	-	-	-	-	-	-	-	-
Trifolium sp.	-	-	x	x	x	x	x	x	x	-	-	-

(*Taraxacum officinalis*), common groundsel (*Senecio vulgaris*), sowthistle (*Sonchus sp.*), and spotted cat's ear (*Hypochaeris radicata*) were in the latter category. The broadleaf category in the 'seed' treatment contained wild carrot (*Daucus carota*), clover (*Trifolium sp.*), common groundsel (*Senecio vulgaris*), red sorrel (*Rumex acetosella*), sowthistle (*Sonchus sp.*), spotted cat's ear (*Hypochaeris radicata*), and yarrow (*Achillea millefolium*) (Table 3.1.). The main difference between the 'resident' and the 'seed' treatment was the presence ('seed') or absence ('resident') of legumes (*Fabaceae*) and the higher percentage of plants from the sunflower family (*Asteraceae*) in the 'resident' treatment (data not shown).

In the following spring (prebloom 1997) and early summer (fruit set 1997), the 'grass' plots had three broadleaf plant species (Table 3.1.). Clover (*Trifolium sp.*), forget-me-not (*Myosotis laxa*), and buckhorn plantain (*Plantago lanceolata*) were identified at prebloom, clover (*Trifolium sp.*), sowthistle (*Sonchus sp.*) and spotted cat's ear (*Hypochaeris radicata*) at fruit set (Table 3.1.). These broadleaf plants accounted for less than 5% of the covered area. More than 95% were gramineous plants (Table 3.1.). The two more diverse treatments had four ('resident') and five ('seed') broadleaf species, respectively, in spring and summer (prebloom and fruit set 1997, Table 3.1.). The relative abundance of gramineous plants was 80% in the 'resident' treatment on both survey dates (prebloom and fruit set 1997). In the 'seed' treatment, 70% (prebloom 1997) and 75% (fruit set 1997) were recorded (Table 3.1.). The main difference between the two diverse treatments was again the higher percentage of legumes (*Fabaceae*) in the 'seed' treatment versus the higher percentage of plants from the sunflower family (*Asteraceae*) in the 'resident' treatment (data not shown). Later in the summer (veraison 1997), the number of broadleaf plant species decreased drastically in all treatments (Table 3.1.). The relative abundance of gramineous plants increased from spring to late summer (at veraison 1997) in each treatment: up to almost 100% gramineous plants in the 'grass' plots, 85% in the 'resident' plots, and 95% in the 'seed' plots (Table 3.1.). Spotted cat's ear (*Hypochaeris radicata*) remained the only flowering broadleaf plant in the more diverse treatments later in the season (Table 3.1.).

The frequency distribution of the numbers of plant species at the flowering stage per sample unit (5.5 m transect) for the four sampling days is shown in Figure 3.1. The number of plant species in the 'grass' treatment ranged from one to three per sample unit at prebloom 1996 (Figure 3.1.A.), two to four one year later (prebloom and fruit set 1997, Figure 3.1.B. and 3.1.C.), and only one species remained in all samples at veraison 1997 (Figure 3.1.D.).

Two to five species were counted in the 'resident' treatment at prebloom 1996 (Figure 3.1.A.) and prebloom 1997 (Figure 3.1.B.), two to four species at fruit set 1997 (Figure 3.1.C.), and one to two species in late summer (veraison 1997, Figure 3.1.D.).

In the 'seed' plot, the number ranged from two to six plant species at prebloom 1996 (Figure 3.1.A.). One year later, at prebloom 1997, it had four to six species (Figure 3.1.B.), three to six species in mid-summer (fruit set 1997, Figure

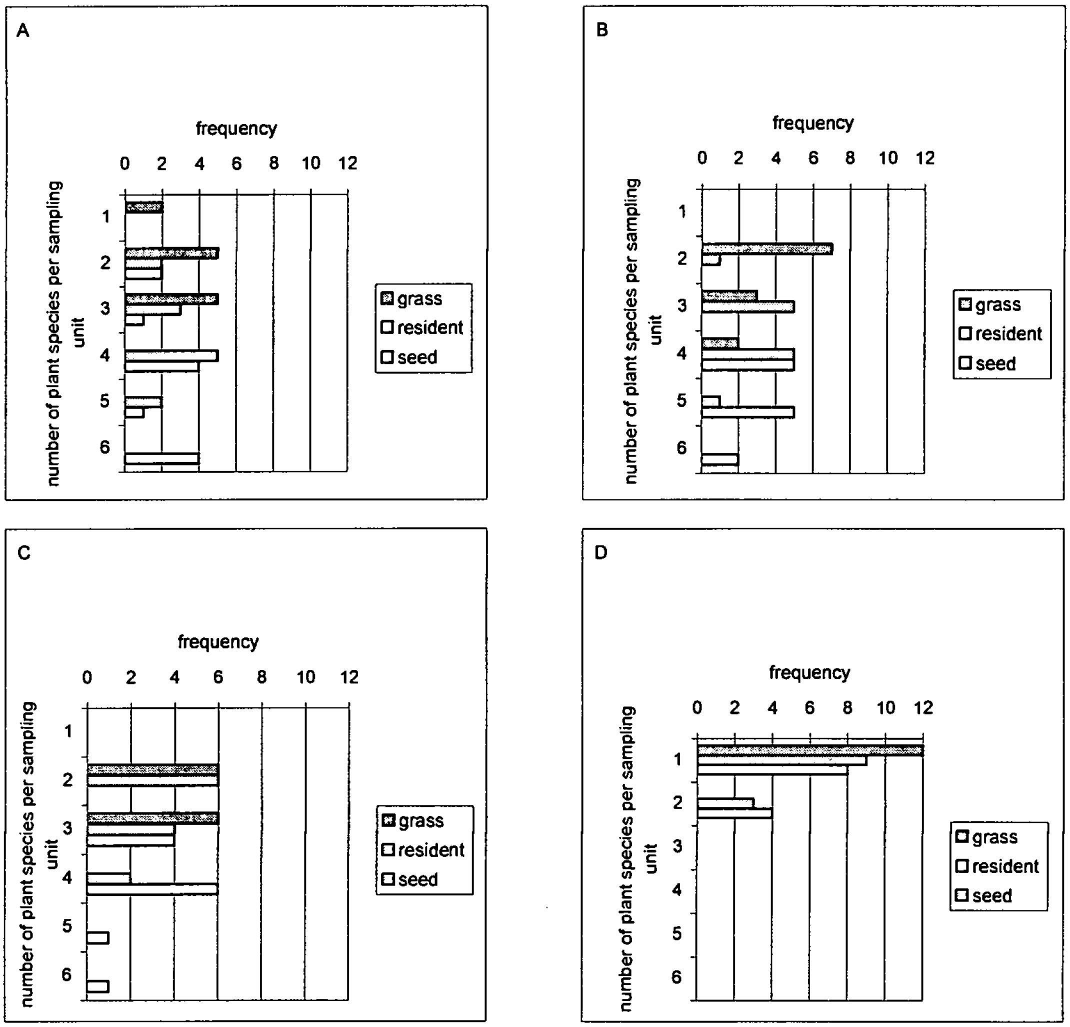

Figure 3.1. Frequency histograms for the number of plant species per sample unit. The sample unit was a 5.5-m transect. Plant species at the flowering stage that touched the transect were counted at prebloom 1996 (A), prebloom 1997 (B), fruit set 1997 (C), and veraison 1997 (D). For statistical analysis see Appendix A.

3.1.C.), and one to four species per sample unit in late summer (veraison 1997, Figure 3.1.D.).

The contrast p-values for the number of plant species at the scale of the sample unit are shown in Table 3.2. At prebloom in both years, the number of plant species was significantly lower in the 'grass' treatment compared to the 'resident'and 'seed' treatments (contrast p-values: 0.0067 and 0.0005 for 1996 and 1997, respectively, Table 3.2.). At fruit set 1997, the plant species number was still lower in the 'grass' treatment (contrast p-value: 0.0279, Table 3.2.). Later in the season (veraison 1997), the number of plant species was not different among the treatments (contrast p-value: 0.0808, Table 3.2.). The second contrast, which

Table 3.2. Contrast p-values for the number of plant species at the scale of the sample unit at three grapevine growth stages. The p-values indicate the significance of the differences for the number of plant species.

	contrasts	prebloom	fruit set	veraison
		p-values		
1996	grass vs. resident & seed	0.0067		
	resident vs. seed	0.2162		
1997	grass vs. resident & seed	0.0005	0.0279	0.0808
	resident vs. seed	0.0049	0.0059	0.6381
treatment effects	grass vs. resident & seed	0.0001		
	resident vs. seed	0.0895		
year effects	grass vs. resident & seed	0.0977		
	resident vs. seed	0.4128		
treatment x year	grass vs. resident & seed	0.5635		
	resident vs. seed	0.2350		

compared the two diverse treatments ('resident' and 'seed') with each other, showed no difference concerning the number of plant species per sample unit at prebloom 1996 (Table 3.2.). During the second year, at prebloom and fruit set 1997, the 'seed' treatment contained more flowering plant species (contrast p-values: 0.0049 and 0.0059 for prebloom and fruit set, respectively, Table 3.2.). No differences were detected at veraison 1997 (Table 3.2.).

The treatment by year interaction at prebloom was not significant (Table 3.2.). No year effects were detected for the spring survey. The differences were due to treatment effects (Table 3.2.).

Vegetative growth

The grapevine canopies were thinned according to their vigor. An average of 24 shoots per vine was left in the 'resident' and 'seed' treatments. In the 'grass' treatment, only an average of 17 shoots per vine was available in 1996 and 19 shoots per vine in 1997 because the grapevines showed low vigor. Vegetative growth as affected by the experimental treatments and the p-values for the set of contrasts are shown in Table 3.3. In both years (1996 and 1997) the total shoot length was increased in plots with more diverse plant communities (contrast p-values: 0.0010 and 0.0267 for 1996 and 1997, respectively, Table 3.3.). Also in both years, the average leaf size was larger (contrast p-values: 0.0032 and 0.0290

Table 3.3. Vegetative growth of the grapevine during the 1996 and 1997 seasons.

			shoot length (cm)	shoot diameter (mm)	main shoot leaf area per vine (m2)	lateral shoot leaf area per vine (m2)	average leaf size (cm2)	% lateral leaf area
1996	grass		82.8	7.7	1.929	0.813	47.8	22.9
	resident		110.4	8.5	4.235	2.264	62.3	20.3
	seed		102.6	8.7	3.359	1.381	69.4	19.6
	ANOVA	p =	0.0026	0.1335	0.0862	0.2318	0.0076	0.2744
contrasts	grass vs. resident & seed	p =	0.0010	0.0579	0.0422	0.1725	0.0032	0.1250
	resident vs. seed	p =	0.2038	0.5626	0.3618	0.2909	0.2103	0.7214
1997	grass		71.1	5.4	1.726	0.628	50.5	21.0
	resident		126.4	7.7	3.059	1.315	64.5	28.0
	seed		108.7	7.2	2.616	1.396	61.3	26.7
	ANOVA	p =	0.0610	0.0106	0.1240	0.4231	0.0735	0.5580
contrasts	grass vs. resident & seed	p =	0.0267	0.0037	0.0573	0.2038	0.0290	0.3001
	resident vs. seed	p =	0.4055	0.4707	0.4709	0.8971	0.5723	0.8511
treatment effects								
	grass		77.0	6.6	1.828	0.721	49.2	22.0
	resident		118.4	8.1	3.647	1.790	63.4	24.2
	seed		105.7	8.0	2.988	1.389	65.4	23.2
	ANOVA	p =	0.0212	0.0191	0.0172	0.1232	0.0053	0.8516
contrasts	grass vs. resident & seed	p =	0.0007	0.0004	0.0011	0.0117	0.0001	0.4766
	resident vs. seed	p =	0.3606	0.8475	0.2111	0.4647	0.5702	0.829
year effects								
	1996		98.6	8.3	3.174	1.486	59.8	20.9
	1997		102.1	6.8	2.467	1.113	58.8	25.2
	ANOVA	p =	0.6354	0.0001	0.1670	0.4095	0.7290	0.1139
treatment x year								
	ANOVA	p =	0.3111	0.0438	0.7088	0.6426	0.2932	0.2538

for 1996 and 1997, respectively, Table 3.3.) and the grapevine shoots were thicker (contrast p-value: 0.0579 and 0.0037 for 1996 and 1997, respectively, Table 3.3.) in the more diverse treatments. The main-shoot leaf area per vine was greater in the more diverse treatments (contrast p-values: 0.0422 and 0.0573 for 1996 and 1997, respectively, Table 3.3.). The lateral-shoot leaf area per vine and the ratio of main-shoot to lateral-shoot leaf area was not different among the treatments (Table 3.3.).

Vegetative growth of the grapevines in the two more diverse plots was not different during the two investigated years as indicated by the p-values of the contrast 'resident' versus 'seed' (Table 3.3.).

The treatment by year interaction was significant for the shoot diameters (p-value: 0.0438, Table 3.3.). All other observed differences in vegetative growth were due to treatment effects (Table 3.3.). Across the two seasons, vines in the grass treatment had smaller lateral-shoot leaf areas, although the ratio of lateral to total leaf area was not changed (Table 3.3.).

Leaf gas-exchange and chlorophyll content

Leaf gas-exchange rates (photosynthesis, transpiration), water use efficiency of photosynthesis, and the chlorophyll content of the leaves for three grapevine growth stages are shown in Figure 3.2. All p-values for the corresponding contrasts are listed in Table 3.4. Treatment and year effects and treatment by year interaction are summarized in Table 3.5. The photosynthesis rate was lower for the 'grass'

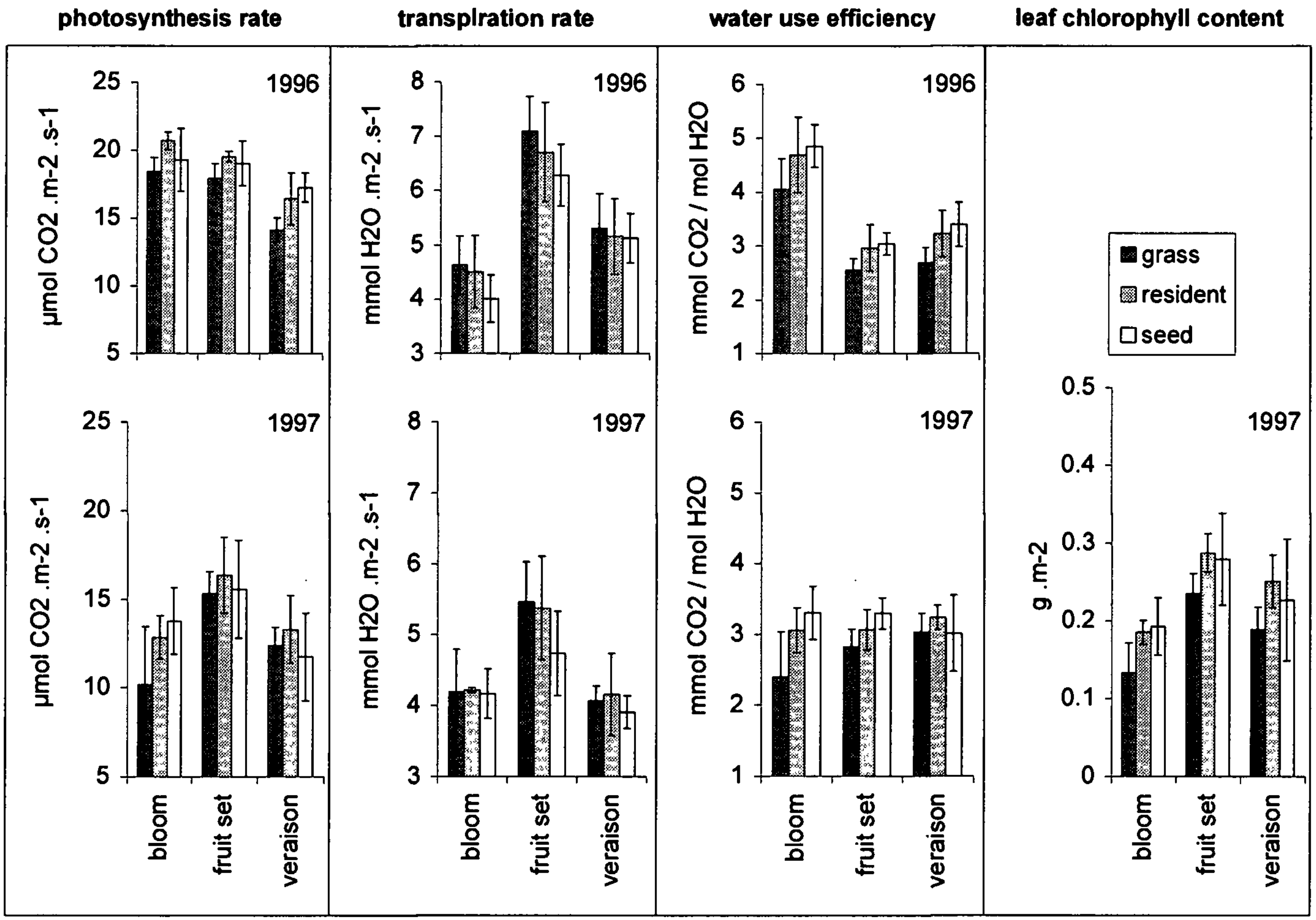

Figure 3.2. Leaf gas-exchange, water use efficiency of photosynthesis, and chlorophyll content. Measurements were conducted at the tenth main-shoot leaf between 9:00 a.m. and 12:00 noon on three different sunny and cloudless days. Vertical lines indicate ± standard errors.

Table 3.4. Contrast p-values for leaf gas-exchange and chlorophyll content during the 1996 and 1997 seasons. The p-values indicate the significance of the contrasts for photosynthesis rate, transpiration rate, the calculated water use efficiency of photosynthesis, and the leaf chlorophyll content at three grapevine growth stages (bloom, fruit set, veraison).

	contrasts	bloom	fruit set	veraison
		p-values		
1996	photosynthesis rate:			
	grass vs. resident & seed	0.1315	0.0833	0.0115
	resident vs. seed	0.2389	0.5650	0.4213
	transpiration rate:			
	grass vs. resident & seed	0.3164	0.2238	0.6958
	resident vs. seed	0.2414	0.4350	0.9455
	water use efficiency of photosynthesis:			
	grass vs. resident & seed	0.0729	0.0371	0.0279
	resident vs. seed	0.6892	0.7100	0.5519
1997	photosynthesis rate:			
	grass vs. resident & seed	0.0567	0.6534	0.9149
	resident vs. seed	0.5888	0.6163	0.2860
	transpiration rate:			
	grass vs. resident & seed	0.9755	0.3213	0.8744
	resident vs. seed	0.8706	0.1913	0.3933
	water use efficiency of photosynthesis:			
	grass vs. resident & seed	0.0255	0.0528	0.6800
	resident vs. seed	0.4723	0.2415	0.4220
1997	leaf chlorophyll content:			
	grass vs. resident & seed	0.0189	0.0804	0.1493
	resident vs. seed	0.7548	0.7729	0.5302

treatment at veraison of 1996 and bloom of 1997 (Table 3.4.). No difference in photosynthesis rate among the treatments was detected at any other measurement date (Table 3.4.). The transpiration rates were not different among the treatments (Table 3.4.). The water use efficiency of photosynthesis tended to be lower for the 'grass' treatment compared to the more diverse treatments (Table 3.4.) except at veraison 1997 (Table 3.4.). The grapevines in the two more diverse treatments showed similar water use efficiencies (Table 3.4.).

Clear differences in chlorophyll content were observed between the two levels of botanical diversity at bloom 1997 (contrast p-value: 0.0189, Table 3.4.),

Table 3.5. Contrast p-values for the treatment effects, year effects, and treatment by year interaction of leaf gas-exchange and chlorophyll content during the 1996 and 1997 seasons. The p-values indicate the significance of the contrasts for photosynthesis rate, transpiration rate, the calculated water use efficiency of photosynthesis, and the leaf chlorophyll content.

	treatment	year	trt x year
photosynthesis rate			
grass vs. resident & seed	0.0537	0.0001	0.1612
resident vs. seed	0.6266	0.0001	0.0876
transpiration rate			
grass vs. resident & seed	0.4333	0.0079	0.5287
resident vs. seed	0.3167	0.0531	0.5244
water use efficiency			
grass vs. resident & seed	0.0065	0.0149	0.1013
resident vs. seed	0.5294	0.0107	0.1736
chlorophyll content			
grass vs. resident & seed	0.0075		
resident vs. seed	0.7957		

these differences became smaller over the course of the season (Table 3.4.). The grapevine leaves in the 'resident' and the 'seed' treatments had similar chlorophyll concentrations (Table 3.4.).

Fruit set, fruit yield and composition

The contrast p-values and the treatment means for percent fruit set, fruit yield and fruit composition are shown in Table 3.6. The grapes of all treatments were harvested on the same day (October 10, 1996 and October 7, 1997). The juice soluble solids (Brix) were higher in plots with more diverse vegetation (contrast p-values: 0.0148 and 0.0004 for 1996 and 1997, respectively, Table 3.6.). Percent fruit set, titratable acidity, and pH were similar in all treatments (Table 3.6.). In 1997, the fruit yield was slightly lower in the 'grass' treatment compared to the more diverse treatments, mainly due to lower yield per shoot and slightly smaller cluster weights (Table 3.6.). The crop parameters for the 'resident' and the 'seed' treatment were similar in both years (Table 3.6.).

The treatment by year interaction is not significant for any crop parameter (Table 3.6.). The year effects were much more pronounced than the treatment effects. All year effects for the measured crop parameters were significant except for percent fruit set (Table 3.6.).

Table 3.6. Fruit set, yield, and fruit composition at harvest 1996 and 1997.

			percent fruit set	yield per m2 (kg)	yield per shoot (g)	cluster weight (g)	soluble solids (Brix)	titratable acidity (g/l)	pH
1996	grass		27.0	0.452	120.4	98.9	22.13	8.79	3.06
	resident		24.8	0.983	197.3	133.3	22.97	9.21	3.05
	seed		26.5	0.665	158.2	128.4	23.05	9.04	3.08
	ANOVA	p =	0.7706	0.2836	0.2194	0.2492	0.0431	0.8603	0.2084
contrasts	grass vs. resident & seed	p =	0.6237	0.2035	0.1365	0.1073	0.0148	0.6246	0.6932
	resident vs. seed	p =	0.6104	0.3370	0.3590	0.8163	0.8181	0.8291	0.0908
1997	grass		32.7	0.274	87.9	65.5	21.16	7.08	2.96
	resident		34.7	0.701	195.3	110.8	21.85	7.27	2.92
	seed		29.5	0.490	131.9	86.0	22.19	6.74	2.93
	ANOVA	p =	0.8853	0.0882	0.0597	0.1319	0.0010	0.4772	0.4795
contrasts	grass vs. resident & seed	p =	0.9529	0.0548	0.0497	0.0910	0.0004	0.8502	0.2484
	resident vs. seed	p =	0.6337	0.2416	0.1346	0.2462	0.0945	0.2418	0.7926
treatment effects									
	grass		29.8	0.363	104.2	82.2	21.65	7.9	3.01
	resident		29.7	0.842	196.3	122.1	22.41	8.24	2.99
	seed		28.0	0.578	145.1	107.2	22.62	7.89	3.01
	ANOVA	p =	0.9496	0.1846	0.1047	0.1613	0.0065	0.7932	0.5451
contrasts	grass vs. resident & seed	p =	0.8007	0.0388	0.0154	0.0184	0.0001	0.6944	0.3412
	resident vs. seed	p =	0.8254	0.3627	0.1667	0.4994	0.4126	0.6168	0.4468
year effects									
	1996		26.1	0.700	158.6	120.2	22.72	9.01	3.06
	1997		32.3	0.488	138.4	87.4	21.73	7.03	2.94
	ANOVA	p =	0.1099	0.0131	0.0405	0.0004	0.0001	0.0001	0.0001
treatment x year									
	ANOVA	p=	0.7326	0.7761	0.3444	0.4266	0.6249	0.5680	0.1602

Discussion

In the spring surveys of the more diverse treatments, the number of plant species at the flowering stage at the scale of the plots ranged from five to eight. Elmore (1989) found similar ranges in spring surveys (April) in two almond orchards in California. In both orchards, vegetation management was thought to be of prime importance for the weed species number. Navas and Goulard (1991) identified seven plant species in an April survey of a herbicide treated vineyard in France. Remund *et al.* (1989, 1992) surveyed 21 vineyards in Eastern Switzerland and counted 21 to 65 plant species during the month of May. It still needs to be investigated if the number of flowering plant species and the relative abundance of gramineous and broadleaf plants at specific grapevine growth stages provide sufficient data to compare plant diversity in vineyards that are mowed two to four times per year.

Testing botanical uniformity versus botanical diversity in the field situation demanded a number of compromises in order to initiate and carry out an experiment of such complexity. After the initial disturbance and treatment application, the vegetation was managed equally in all treatment plots. These management practices (low intensity) influenced both, botanical diversity (or uniformity) and grapevine performance. The initial idea for the experiment was to decrease management intensity as a first step and to make subsequent vegetation patterns visible.

The vineyard soil has a high clay content, low pH, and is generally wet in the spring. Under such conditions, intensive management practices accelerate the alteration of physical soil properties (Hess and Oertli, 1991). Similar soil conditions probably contributed to decreased vine root development (especially feeder roots) below a grass cover crop and subsequent reduction of vegetative growth as reported in an earlier study in Oregon (Lombard *et al.*, 1988). Soil compaction combined with frequent mowing may select for plants with shallow, fibrous roots. The growth of grapevine feeder roots is very limited and anaerobic conditions, drought (Hess and Oertli, 1991; Hess, 1994), low nitrogen concentration, and allelopathy, if present, act upon continuously fewer grapevine feeder roots causing an imbalance in the root to shoot ratio. Decreased growth of feeder roots could result in decreased grapevine efficiency and can not be fixed with increasing chemical input (Hess and Oertli, 1991).

Vegetation studies in vineyards have been performed with a multitude of trellis systems and management practices (Dorigoni *et al.*, 1991; Lombard *et al.*, 1988; Maigre, 1996; Saayman and Van Huyssteen, 1983). None of these studies compared levels of botanical diversity. More experiments with a defined set of grapevine performance parameters, including the timing of data collection, are necessary to test diverse plant communities on additional sites. Soil parameters that may influence grapevine performance such as differences in soil structure, water and nutrient availability, amount and composition of the organic matter should be addressed simultaneously in future experiments (see Hanna *et al.*, 1996) on several sites, for several years and include management practices in the analysis.

In the present study, data from two seasons showed balanced vegetative growth in more diverse plots early in the season (April, May, June) and advanced fruit ripening, as judged by the juice soluble solids, later in the season (September, October). Vines in the 'grass' treatment became progressively less vigorous, developed smaller leaves with lower chlorophyll content. The treatment by year interaction was significant only for shoot diameter. This was probably closely related to the number of shoots left on the vines and influenced by pruning and canopy management. The sugar content of the juice (soluble solids) is often the decisive factor to determine maturity of the grapevines in the Willamette Valley. Swift and Anderson (1994) hypothesized that botanical diversity is more important during rapid vegetative growth than later in the season when the fruit matures and the crop plants become progressively more independent of soil conditions. Mild water stress might be desirable during the ripening phase for increased fruit quality (Kozlowsky *et al.*, 1991; Smart and Smith, 1988). This experiment showed that the fruit in botanically more diverse plots could mature ahead of the fruit in botanically more uniform ('grass') plots, even with a higher crop load.

The water use efficiency of photosynthesis tended to be lower in the uniform treatment than in the diverse treatments, except at veraison 1997. Larcher (1995) pointed out that climatic conditions, leaf development, leaf age, and stress situations affect the water use efficiency at the scale of the whole plant. The climatic conditions were the same for all leaves in all treatment plots. But the stress situation for the grapevines in the 'grass' treatment was more severe, especially during the first half of both seasons: the leaves were smaller and senesced earlier. In 1997, the chlorophyll content was lower at prebloom. Large variances in photosynthesis and transpiration rates suggest that additional factors beside the treatment effects (e.g. soil hydrology) might have affected leaf gas-exchange.

For experimental purpose, all treatments were maintained as 100% covers, within and between the rows. This was done to expose the entire grapevine root systems to the same growing conditions. Practical management strategies for vineyards combine occasional soil cultivation with cover cropping (Hess and Oertli, 1991). Resident weeds should be included in a diverse plant community because these plants are site-adapted and easier to establish (Fox and Straub, 1993; Gut *et al.*, 1995; Perret *et al.*, 1989).

It is apparent from the results of this study that a cover crop of perennial grass maintained for several seasons may impart a high degree of competition to grapevines. In non-irrigated vineyards, this competition can lead to a progressive devigoration of the vines without the benefits of better fruit quality. More diverse ground covers have the desirable functional attributes of the grass monoculture such as reducing soil erosion and surface water runoff on hillsides, maintaining soil organic matter and nutrient levels by reducing leaching of nitrate and other nutrients, and improving soil structure. In addition, more diverse ground covers may contribute to ecological stability and be less competitive to the grapevine.

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Chapter 4: Spatial Distribution of Botanical Diversity in Commercial Vineyard Sites in Oregon

Abstract

Four commercial vineyards in the Willamette Valley in Oregon were surveyed to establish a list and number of resident (weedy) plant species.

At the scale of the whole vineyards, 9, 10, 11, and 13 plant species, respectively, were observed. Five species occurred in all four sites. Frequency histograms showed that most often four or five plant species were observed at the smaller scale of the sample unit (5.5 m transect) with ranges from one to six species in two vineyards, one to five and two to six, respectively, in the two other vineyards.

The data sets indicated that the plant species number was not in all cases randomly distributed over the vineyard. The west-east arrangement of the data showed a continuous trend from lower to higher numbers of plant species in Vineyard 1. In Vineyard 3, the west-east arrangement of the data showed a patch of lower numbers of plant species in a small part of the field. The observations in the other two vineyards did not indicate patterns or trends on a west-east arrangement.

Introduction

Many botanical field studies describe the composition of the plant community by surveying and extrapolating small representative parts of a larger field (Dessaint *et al.*, 1991; Fardossi *et al.*, 1996; Mahdi and Law, 1987; Navas and Goulard, 1991; Remund *et al.*, 1989, 1992). It was assumed that the vegetation was either fairly uniform or the patterns repeated over the entire studied area. Levin (1992) emphasized choosing the scale of an ecological study from the processes that form the patterns rather than from the visible patterns themselves. Assuming that management practices mask underlying processes in agro-ecosystems, management itself is the dominant process and the extent of a study should be the entire managed plot or field. This approach was taken in some studies (Elmore *et al.*, 1989; Holt *et al.* 1995).

Managing weeds in a vineyard is considered habitat management in the frame of integrated pest management and integrated production (Boller, 1992). Remund *et al.* (1992) reported increasing arthropod diversity with increasing numbers of flowering plant species in 21 commercial vineyard sites in Eastern Switzerland. The number of plant species and the composition of the plant community are of prime importance to minimize pesticide and fertilizer input in agro-ecosystems (IOBC, 1993). Fox and Straub (1993) recommend combining the resident vegetation with commercially available plants (low seeding rates) that have desired attributes for a diverse plant community. Such attributes should effectively assist management input or replace management tools. Desirable plant attributes include attracting beneficial arthropods (Remund *et al.*, 1989; 1992), fixing atmospheric nitrogen (*Fabaceae*), growing rapidly and maturing early in spring, like *Poa annua*, *Stellaria media*, *Veronica sp.* (Perret and Koblet, 1973), and ability to expand the root system in poorly aerated soils, like *Raphanus sp.* (Perret, 1982).

The scope of interest in this study was to establish a list of resident plant species and to describe the distribution of plant species within the boundaries of the vineyard. The two scales addressed were the approximate grapevine spacing (5.5 m transects) and the extent of the vineyards.

Some grape growers in Oregon favor botanical diversity over a grass monoculture in the vineyard. They have changed vegetation management practices recently to increase botanical diversity.

Materials and Methods

The survey was carried out in four vineyards between late May and mid-June 1997. All vineyards had rows with approximately the same length (180 m.). Three samples were taken in every sixth row-middle. The number of samples increased with increasing number of rows. The sample unit was a 5.5 m-transect, which was placed randomly but always parallel to the row orientation. The sampling tool was a string (5.5 m) and two screwdrivers at each end to tighten the string. Any plant at the flowering stage that touched the string was counted and identified. Gramineous plant species (*Poaceae*), thistles (*Cirsium sp.*), geraniums (*Geranium sp.*), and sowthistle (*Sonchus sp.*) were identified at the genus level.

Soil and vegetation management practices in the four surveyed vineyards are summarized in Table 4.1. Vineyard 1 was mowed once in early April 1997, before the survey was carried out in June. All rows were mowed twice during 1996. In addition, every other row in the western half of the vineyard was cultivated in

Table 4.1. Soil and vegetation management summaries for four commercial vineyards in Oregon.

Vineyard	mowing frequency (per year)	% surface mowed	time since last cultivation
1 (East)	2 times	50	> 5 years
1 (West)	2 times	50	1 year (in alternate rows)
2	3 times	100	> 5 years
3	3 times	100	5 years (only 4 rows)
4	2 times	100	> 5 years

spring (1996) and the eastern half was mowed at the same time. Vineyard 2 was mowed once in April 1997 and three times per season in the previous years. Vineyard 3 was mowed once (early May 1997) in the survey year. Four rows were cultivated 5 years prior to the survey to be replanted with grapevines. Since then, the whole vineyard was mowed three times a year. In one wet spot that had running water every spring, oil seed radish (*Raphanus sp.*) was sown by hand three months before the survey was conducted. Vineyard 4 was mowed twice per season in the previous years. None of the vineyards was irrigated.

Results

Table 4.2. shows a list of flowering plant species at the scale of the whole vineyards and the total number of species which is the counted total over all 5.5 m transects. The number of plant species ranged from 9 (Vineyard 1) to 13 (Vineyard 4) species. Gramineous plants were dominant in all four sites. In the broadleaf category, geranium (*Geranium sp.*), spotted cat's ear (*Hypochaeris radicata*), red sorrel (*Rumex acetosella*), sowthistle (*Sonchus sp.*), and hop clover (*Trifolium dubium*) occurred in all sites. The oil seed radish (*Raphanus sp.*) was sown into Vineyard 3. Ten other broadleaf plant species occurred in at least one of the surveyed vineyards: english daisy (*Bellis perennis*), oxeye daisy (*Chrisanthemum leucanthemum*), thistle (*Cirsium sp.*), bindweed (*Convolvulus arvensis*), wild carrot (*Daucus carota*), small flowered lotus (*Lotus micranthus*), forget-me-not (*Myosotis laxa*), buckhorn plantain (*Plantago lanceolata*), common groundsel (*Senecio vulgaris*), and white clover (*Trifolium repens*).

Table 4.2. Plant composition of the vineyard floor in four commercial vineyards. The total number of flowering plant species are shown for the scale of the vineyards. The samples were taken between late May and mid-June. The lower part of the table includes a list of observed flowering plants.

prebloom 1997	Vineyard 1	Vineyard 2	Vineyard 3	Vineyard 4
total number of plant species at the scale of the vineyard	9	11	10	13
gramineous plants				
Festuca sp.	x	x		
Lolium multiflorum				x
Poa annua			x	
broadleaf plants				
Bellis perennis	x	x	-	x
Chrisanthemum leucanth.	-	-	x	x
Cirsium sp.	-	-	x	x
Convolvulus arvensis	-	-	-	x
Daucus carota	-	-	-	x
Geranium sp.	x	x	x	x
Hypochaeris radicata	x	x	x	x
Lotus micranthus	-	x	-	x
Myosotis laxa	-	x	-	-
Plantago lanceolata	x	x	x	-
Raphanus sp.	-	-	x	-
Rumex acetosella	x	x	x	x
Senecio vulgaris	-	x	-	-
Sonchus sp.	x	x	x	x
Trifolium dubium	x	x	x	x
Trifolium repens	x	-	-	x

Frequency histograms describe the distribution of the plant species number per sample unit (5.5 m transect) in the four vineyards (Figure 4.1.). In all vineyards, three and four species, with a range from one to six, were most often counted at the scale of the sample unit. These plants were resident (weedy) species of the sites (except oil seed radish).

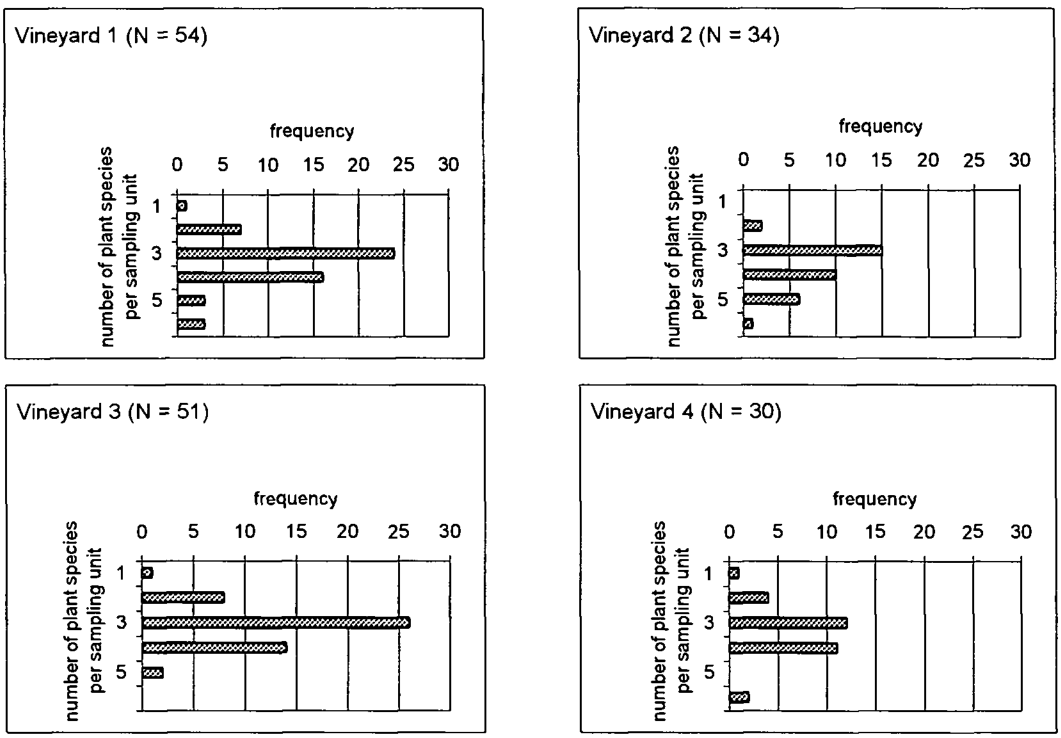

Figure 4.1. Frequency histograms for the number of plant species per sample unit in four commercial vineyards. The sample unit was a 5.5 m transect. Plant species at flowering stage that touched the transects were counted. For statistical analysis see Appendix B.

In Vineyards 1 and 3, the sample data were not randomly distributed and therefore, spatial independence of the data can not be assumed. The univariate statistics are summarized in Appendix B. The west-east arrangement of the sample data (Figure 4.2.) showed a trend from lower numbers to higher numbers of plant species in Vineyard 1 and the data set of Vineyard 3 showed lower numbers of

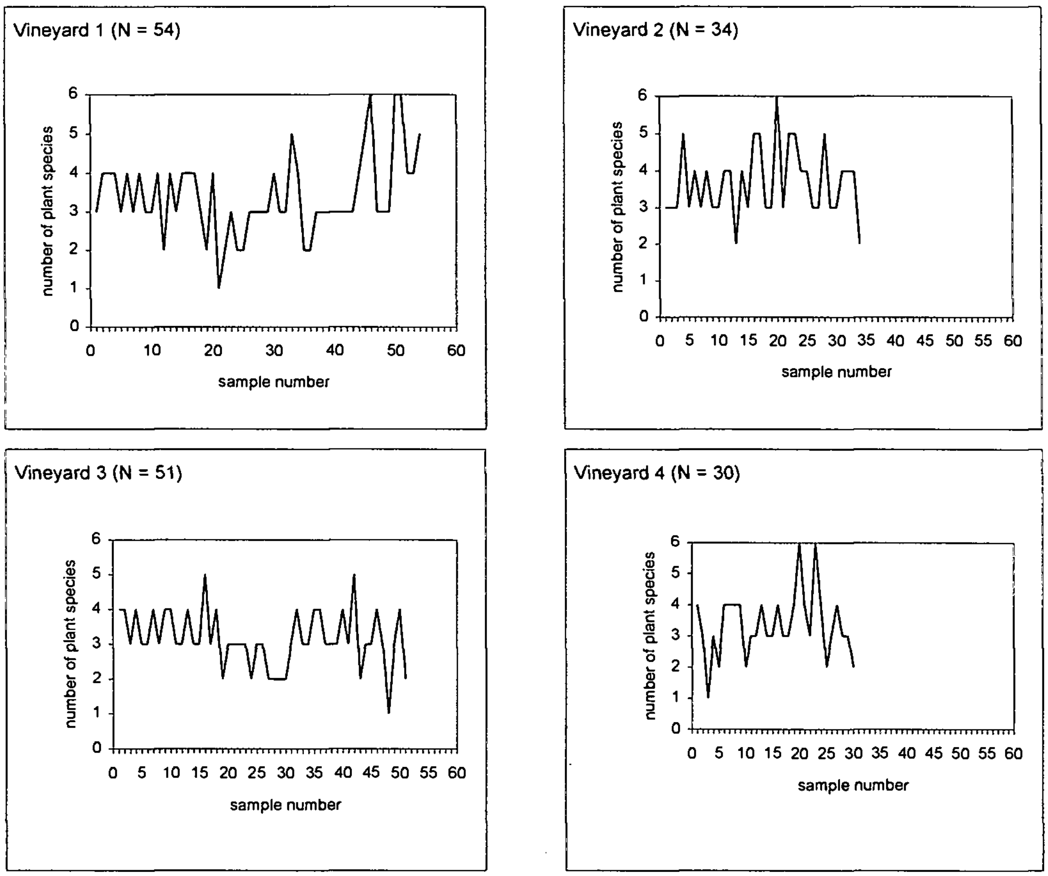

Figure 4.2. One-dimensional spatial distribution of the number of plant species per sample unit in four commercial vineyards. The observations are arranged from west to east for each sampled vineyard. The sample units were 5.5 m transects in the row middle of every sixth row.

plant species from samples 20 through 30. No clear indications for patterns or trends were visible in the data sets of Vineyards 2 and 4.

Discussion

Although the number of plant species was very similar in all four vineyards, the one-dimensional arrangement of the sample data from west to east, as sampled in the field, revealed additional information about their spatial distribution in the vineyards.

The trend (Vineyard 1) and pattern (Vineyard 3) of the data suggest that management practices need fine-tuning only in those parts of the vineyards that contain fewer plant species. Vineyard 1 was grass (*Festuca sp.*) dominated on the east side with only some patches of hop clover (*Trifolium dubium*), spotted cat's ear (*Hypochaeris radicata*), and english daisy (*Bellis perennis*) beside a few buckhorn plantains (*Plantago lanceolata*), sowthistles (*Sonchus sp.*), and geraniums (*Geranium sp.*). The west side which was cultivated during the previous season contained the same plant species but more abundant and had also patches of white clover (*Trifolium repens*) and red sorrel (*Rumex acetosella*). The pattern in Vineyard 3 is due to different stand densities of the same plant species. All four rows that were cultivated five years before the survey was carried out had lots of bare ground with only a few plants emerging, possibly caused by repeatedly driving through the vineyard in wet soil conditions before the ground cover established. Further experiments are necessary to determine the exact timing of soil and vegetation management practices in the integrated production frame for vineyards under Oregon weather conditions.

Vineyards 1 and 2 contained a variety of plant species that were present as a few single specimens only in the herbicide-treated in-rows. The chosen sampling method did not detect these species although they may be important for this list of resident plants. Botanical and faunistic surveys in 21 vineyards indicated that additional plant species, even if present as a few specimens (< 1%), may significantly increase the number of indifferent and beneficial arthropods (Remund *et al.*, 1992).

Spatial statistics should be considered, beside parametric statistics, for an unbiased estimator of the data variation that includes the location of the observation and provides a description if and where spatial features (trends, patterns, degree of continuity, and extreme values) exist in a surveyed field (Turner *et al.*, 1991). Turner *et al.* (1991) provide summaries of 13 quantitative methods for landscape ecology. These methods may also be used for the analysis of vegetation patterns in agricultural ecosystems (J.A. Jones, Dept. of Geosciences, OSU, personal communication, 1997), in which management is often the dominant process that forms the observed patterns of the plant community (Elmore, 1989; Gut *et al.*, 1995; Remund *et al.*, 1989). Rossi *et al.* (1992) offered a comprehensive and practical introduction for the use of geostatistical tools to analyze and interpret ecological spatial dependence.

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Chapter 5: Conclusion

Plots with a more diverse plant community showed better overall grapevine performance though not all measured parameters improved significantly. Further experiments and additional sites with levels of botanical diversity manipulated as treatments are necessary. Several properties of the agro-ecosystem need to be quantified simultaneously. The use of spatial statistics in agro-ecology could reveal more insight how soil properties and management practices impact vineyard-ecosystems at the two scales of the grapevine spacing and the entire field.

The broader goal of the present study was to apply principles and ideas from an existing Integrated Production model into a typical vineyard in Oregon. The resulting example needs to be exposed to judgment and criticism, to encourage discussions and further experiments, and to go beyond case studies eventually.

The four surveyed vineyards had a certain degree of botanical diversity. More research is needed to determine clearly, how many plant species and what attributes of plants could be of agronomic interest for diverse ground covers in Oregon vineyards.

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Appendices

Appendix A: statistical data summaries for the number of plant species per treatment in the experimental plots

prebloom 1996

	grass	resident	seed
N	4	4	4
Mean	2.25	3.583333	4.33333
Std Error	0.4194	0.5	0.8165
CV	33.501	27.801	34.557
Skewness	-1.1293	-0.3704	0.5443
Min	1.66667	3	3.66667
Median	2.3333	3.6667	4.1667
Max	2.66667	4	5.33333

prebloom 1997

	grass	resident	seed
N	4	4	4
Mean	2.58333	3.5	4.75
Std Error	0.1667	0.5773	0.5693
CV	30.695	22.792	15.869
Skewness	-2	1.5396	-0.7528
Min	2.3333	3	4
Median	2.6667	3.3333	4.8334
Max	2.6667	4.3333	5.3333

fruit set 1997

	grass	resident	seed
N	4	4	4
Mean	2.5	2.666667	3.91667
Std Error	0.3333	0.2722	0.7391
CV	20.889	29.194	22.987
Skewness	-2	0	-0.4816
Min	2	2.6667	3
Median	2.6667	2.6667	4
Max	2.6667	3	4.3333

veraison 1997

	grass	resident	seed
N	4	4	4
Mean	1	1.5	1.33333
Std Error	0	0.4303	0.4714
CV	0	36.181	36.927
Skewness	~	0	1.4142
Min	1	1	1
Median	1	1.5	1.6667
Max	1	2	2

Appendix B: statistical data summaries for the number of plant species per sampling unit in four commercial vineyards

Vineyard 1

N	54
Mean	3.40741
Std Error	1.03739
CV	30.445
Skewness	0.57279
Min	1
Median	3
Max	6

Vineyard 2

N	34
Mean	3.67647
Std Error	0.94454
CV	25.6915
Skewness	0.48626
Min	2
Median	3.5
Max	6

Vineyard 3

N	51
Mean	3.15686
Std Error	0.80926
CV	25.6349
Skewness	-0.0631
Min	1
Median	3
Max	5

Vineyard 4

N	30
Mean	3.36667
Std Error	1.0662
CV	31.6693
Skewness	0.46509
Min	1
Median	3
Max	6