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Integrated Production:
Impact of Vineyard Floor Biodiversity on Vine Performance

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INTRODUCTION

Increasing ecological awareness led to the conceptual ization and implementation of sustainable production systems such as Integrated Production. Integrated Production (IP) aims at achieving optimum yields of high quality fruit utilizing environmentally safe procedures. Priority is given to the utilization and enhancement of natural regulating processes and to the reduction of pesticides and fertilizers. The concept of IP requires the optimization of all measures taken by the grape grower to avoid inappropriate activities that exert a negative impact on the agro-ecosystem.

The crucial element of Integrated Production in viticulture is the ecological diversification of the vineyard agro-ecosystem and the maintenance of its ecological stability by minimizing potentially disturbing factors (Boller, 1992). The green cover is utilized to increase biodiversity and ecological stability.

Biodiversity refers to all species of plants, animals, and microorganisms existing and interacting within an ecosystem (McNeeley *et al.*, 1990). For years, ecologists have debated the assumption that increased diversity fosters stability. Critical theoretical reviews on this subject are available (Altrieri, 1994; Goodman, 1975), as well as reviews that use agricultural examples to bolster the theory (Pimentel, 1961; Root, 1973; Dempster and Coaker, 1974; Listinger and Moody, 1976; Perrin, 1977). Ecosystems in which plant species are intermingled possess an associational resistance to herbivores in addition to the resistance of individual plant species (Root, 1975).

Based on studies of plant-pest associations, Root (1973) concluded that there is a greater abundance and diversity of natural enemies of pest insects in polycultures than in monocultures. Predators tend to be polyphagous and have broad habitat requirements, so they would be expected to encounter a greater array of alternative prey and microhabitats in a heterogeneous environment (Root, 1975). Monocultures do not provide adequate alternative sources of food (pollen, nectar, prey), shelter, or breeding and nesting sites for the effective performance of natural enemies (Rabb *et al.*, 1976). A greater diversity of prey and microhabitats is available within complex environments. As a result, relatively stable populations of generalized predators can persist in these habitats because they can exploit the wide variety of phytophagous arthropods which become available at different times or in different microhabitats (Root, 1973). Diverse habitats offer many important requisites for adult predators and parasites, such as nectar and pollen sources, which are not available in a monoculture, reducing the probability that they will leave or become locally extinct (Risch, 1981).

In a recent review, Andow (1991) identified 209 published studies that deal with the effects of vegetation diversity in agro-ecosystems on herbivorous arthropod species. The majority of the pest species examined in these studies were found to be less abundant in diversified systems than in monocultures.

Studies conducted in Swiss vineyards confirmed that botanical and faunistic diversity are closely related, e.g. with increasing number of plant species, an increase in beneficial arthropods and indifferent phytophagous arthropods was observed, the number of pest species remaining low (Remund *et al.*, 1992; Boller, 1992).

In addition to contributing to ecological stability, green covers reduce soil erosion and surface water runoff on hillsides. They also contribute to maintaining soil organic matter and nutrient levels by reducing leaching of nitrate and other nutrients. Moreover, a green cover may slow the soil compaction process and subsequent loss of pore space in vineyards where traffic follows the same tracks for up to 25 times a year.

Nitrogen input can be greatly reduced through appropriate management of the soil and green cover. The cover crop can be used to synchronize the N availability of the soil with the N-requirement of the grapevine: during periods of low demand, the N-surplus is preserved in the flora; through mulching or mowing about two weeks prior to the period of high demand (fast growing period) N is made available for the vine (Perret *et al.*, 1993).

The presence of flowering plants dramatically increases the faunistic diversity of the vineyard (Remund *et al.*, 1989). An alternate mowing regime (the oldest interrow is mowed when the youngest interrow begins flowering) allows the maintenance of this important equilibrium by assuring the constant supply of flowering plants.

Viticultural production techniques should have a low impact on the environment and promote sustainable production while maintaining profitability. LIVE (Low Input Viticulture and Etiology), the Integrated Production program for Oregon vineyards developed in 1996, encourages farming practices which promote and maintain high biological diversity on the whole vineyard and encourage responsible stewardship of the soil, its health, fertility and stability. LIVE is growing in importance. During 1998, 25% of the Oregon vineyard surface participated in the program.

With the aim of increasing vineyard biodiversity, a replicated trial with three different soil management strategies was established at the OSU Woodhall vineyard in 1995. The effect of the green cover on vine performance was evaluated by measuring photosynthetic rate, water use efficiency, vegetative growth, yield and fruit composition.

MATERIALS AND METHODS

Experimental design

Three different cover crop treatments were established in the spring of 1995 on a 17-year-old Pinot noir block (clone UCD 22) at Woodhall vineyard. Vines are spaced 6 ft x 9 ft. The existing perennial grass cover (Grass), composed predominantly of bentgrass (*Agrostis sp*) is being compared to a treatment where the soil was tilled in spring to allow other resident species to emerge (Resident), particularly broad leaf species, and to a commercial insectary plant mixture of low growing plants sown in spring after tilling (Seed). The plant mixture included the following species: carrot, chervil, coriander, clovers (crimson, white, rose), subclovers, nasturtium, parsley, alyssum and yarrow.

Each green cover treatment was replicated four times, and the replicates consisted of two adjacent interrows (26 vines long). Data was collected in five homogeneous vines per replicate in the rows with the same cover on both sides. The vine rows with different treatments on each side were not used in the experiment. The plots were mowed in alternate rows, three times during the growing season.

Evaluation

The level of competition for water and nutrients imparted by the green covers on the vines, was evaluated by measuring photosynthetic rate, water use efficiency, leaf chlorophyll content, vegetative growth, yield, and fruit composition.

Gas exchange measurements

Gas exchange measurements were carried out at bloom, fruit set and veraison, on the 10th main leaf from the base of one shoot per vine in five vines per replicate (data vines). Leaf gas exchange was measured with a portable infra-red gas analyzer (Ciras-1, PP SYSTEMS, Hitchin, Herts SG5 1RT UK). The measurements were conducted between 9:00 and 12:00 a.m., at photosynthetic flux densities above 1000 umol. m^{-2} . s^{-1} under cloudless skies on fully exposed leaves.

Chlorophyll content

Chlorophyll content was assessed three times during the season on the same leaves sampled for gasexchange immediately after each gas-exchange measurement. A portable non-destructive leaf greenness meter (SPAD-502, Minolta) was used. Chlorophyll content was calculated from the leaf greenness readings using the formula derived by Candolfi-Vasconcelos and co-workers (1994) for Pinot noir: $y = EXP(-3.841942+0.121654*x-0.001264*x^2)$, where x is the SPAD-reading and y is the chlorophyll content in g. m^{-2}.

Vegetative growth

Shoot diameter was measured on the third internode from the base on one shoot per data vine. Shoot length at veraison and number of nodes were used to calculate internode length. Prior to harvest, five shoots per replicate were collected for primary and lateral leaf area measurements. Vines were pruned each year in February or March and pruning weights were used to calculate the Ravaz index (yield : pruning weight).

Yield and fruit composition

Data vines were harvested individually. A sample of 12 clusters per vine was crushed for determination of soluble solids, pH and titratable acidity. A sample of five clusters per vine was used to estimate berry weights, number of berries per cluster and anthocyanin content using a random 100-berry sub-sample. Cluster weight was calculated by averaging the pooled 17 cluster sample.

Statistical analysis

Results from the 1998 season were subjected to analysis of variance. Additionally, the data of the four seasons (1995-1998) was pooled and subjected to a "Treatment x Year" anova. Very few interactions were observed. The main effects and significant interactions are also reported on the tables.

RESULTS AND DISCUSSION

Figure 1 shows gas-exchange and leaf chlorophyll content at bloom, fruit set and veraison, averaged across four growing seasons. Photosynthesis was lower throughout the growing season for plants with a grass cover (Fig. 1). There were no significant differences in the photosynthetic rate of vines with an insectary plant cover or a cover of resident plants during the four seasons. There was no treatment effect on transpiration (Fig. 1). Stomata serve to balance the need for the leaf to allow the entry Of $C0_2$ for photosynthesis while limiting the transpirational loss of water vapor. A measure of the carbon gain in relation to the water loss is the water use efficiency (quotient between photosynthesis and transpiration). Vines on a grass cover, were less efficient in water use than the other two treatments.

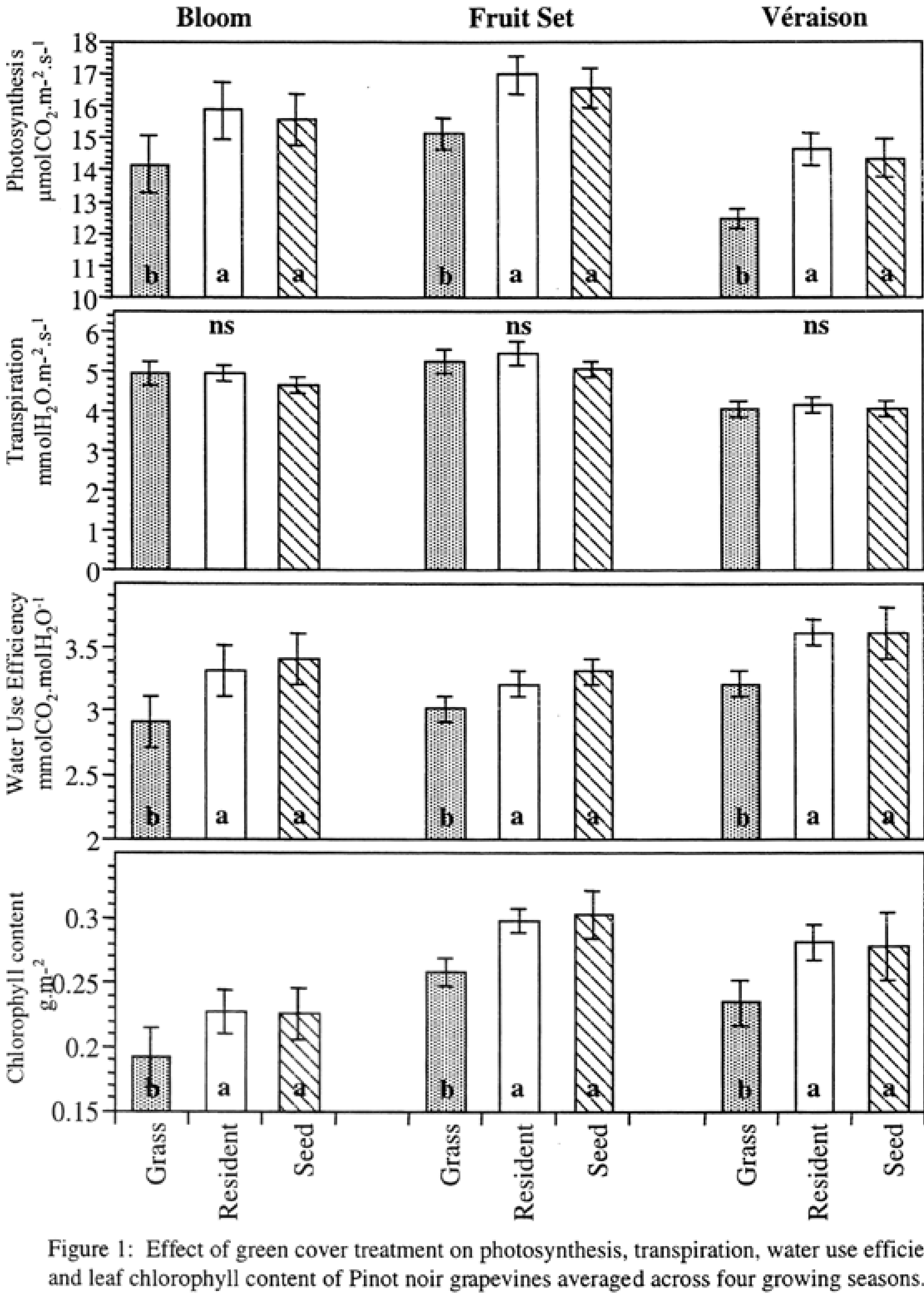

Figure 1: Effect of green cover treatment on photosynthesis, transpiration, water use efficiency, and leaf chlorophyll content of Pinot noir grapevines averaged across four growing seasons. Vertical bars indicate ± standard errors.

Table 1 summarizes the effect of green cover treatment on canopy vegetative growth. In 1998, there were no significant differences among treatments in vegetative growth but the trends observed were similar to the four year average. The four season average shows a depression in the growth of vines growing under a grass cover. Vines in this treatment had smaller and fewer leaves, shorter internodes and thinner shoots. The other two treatments did not differ in vegetative growth.

Table 1: Effect of green cover treatment on canopy vegetative growth of Pinot noir grapevines during the ripening period.

	Main Leaf Size cm^2		Lateral Leaf Size cm^2		Total Leaf Area/Vine. m^2		Lateral Leaf Area % Total	Shoot Diamter mm		Internode Length cm	
1998											
Grass	72		19		1.6		18	6.6		5.8	
Resident	83		26		3.6		19	7.3		5.8	
Seed	86		24		3.5		23	7.1		6.0	
F	ns		ns		ns		ns	ns		ns	
1995-1998											
Treatment											
Grass	82	b	21	b	3.1	b	20	7.0	b	5.4	b
Resident	106	a	30	a	6.0	a	24	8.0	a	6.3	a
Seed	100	a	28	a	5.0	a	23	7.8	a	6.0	ab
F	**		**		**		ns	**		*	
Year											
1995	93	ab	28		7.6	a	22	8.4	a	5.8	
1996	104	a	27		4.6	b	21	8.3	a	6.4	
1997	107	a	25		3.6	b	25	6.8	b	5.6	
1998	80	b	23		2.9	b	20	7.0	b	5.9	
F	*		ns		***		ns	***		ns	
Treatment x Year	ns		ns		ns		ns	ns		ns	

ns, *, **, *** indicate not significant and statistically significant at the 0.05, 0.01, and 0.001 levels, respectively. Values followed by the same letters do not differ significantly.

Yield and yield components of the 1998 season and the four year average are listed in Table 2. In 1998, with the exception of bud fertility (clusters/shoot), there were no significant differences in yield or yield components among treatments. The four year average, however, shows that vines on the "resident" cover had significantly higher yields, followed by the vines on the seed mixture and finally those on grass cover. It is interesting to note that the "Grass" and the "Seed" treatments did not differ in bud fertility. They both had a lower number of clusters per shoot than the "Resident" treatment.

Table 2: Effect of green cover treatment on yield and yield components of Pinot noir grapevines.

	Fruit Yield (Ton/acre)		Berries/ cluster		Berry wt. (g)		Cluster weight (g)		Clusters / shoot		Shoots / vine	
1998												
Grass	0.7		57		1.11		62		1.09	b	9	
Resident	2.3		79		1.09		86		1.51	a	18	
Seed	1.7		72		1.07		78		1.28	ab	13	
F	ns		ns		ns		ns		*		ns	
1995-1998												
Treatment												
Grass	1.6	b	77	b	1.09	b	80	b	1.34	b	16	b
Resident	3.2	a	96	a	1.18	a	110	a	1.64	a	20	a
Seed	2.4	ab	86	ab	1.17	a	100	a	1.44	b	18	ab
F	*		*		*		***		***			
Year												
1995	2.7	a	88	b	1.17	ab	103	ab	1.40	bc	22	a
1996	3.1	a	114	a	1.12	bc	120	ab	1.71	a	20	ab
1997	2.2	ab	73	bc	1.20	a	87	b	1.49	bc	17	bc
1998	1.5	b	69	c	1.09	c	75	b	1.30	c	13	c
F	*		***		*		***		***		***	
Treatment x Year	ns		ns		ns		ns		ns		ns	

[1] ns, *, **, *** indicate not significant and statistically significant at the 0.05, 0.01, and 0.001 levels, respectively. Values followed by the same letters do not differ significantly.

Fruit composition was similar in all treatments in 1998 (Table 3). The four season average also showed no treatment differences in titratable acidity and skin anthocyanins. Juice soluble solids tended to be lower for the grass treatment (Table 3). However, soluble solids were not lower for the grass treatment in 1995, the first year of evaluation or in 1998 (Fig. 2). In 1995, vines in the grass treatment still had sufficient reserves available for remobilization in response to stress. They were growing normally and did not show symptoms of nitrogen deficiency. In 1998, after four seasons of aggressive root-zone competition, these vines showed a tendency toward reduced growth with visible nutrient and drought stress symptoms. They had a very small crop due to low bud fertility. At such low crop levels, it was not difficult to reach adequate ripeness levels.

Table 3: Effect of green cover treatment on fruit composition of Pinot noir grapevines.

		Soluble solids °Brix		pH		Titratable acidity g/L		Skin Anthocyanins mg/berry		Skin Anthocyanins mg/g fruit	
1998											
	Grass	23.0		3.10		7.15		1.52		1.39	
	Resident	23.2		3.03		7.27		1.60		1.48	
	Seed	23.4		3.09		7.23		1.59		1.48	
	F	ns		ns		ns		ns		ns	
1995-1998											
Treatment											
	Grass	22.4	b	3.02	a	7.73		1.33		1.24	
	Resident	22.7	a	2.99	b	8.17		1.40		1.23	
	Seed	23.0	a	3.02	a	7.77		1.45		1.25	
	F	***		*		ns		ns		ns	
Year											
	1995	23.2	a	2.98	b	8.29	b	--		--	
	1996	22.7	b	3.06	a	9.02	a	1.46	a	1.31	a
	1997	21.7	c	2.93	c	7.03	c	1.15	b	0.97	b
	1998	23.2	a	3.07	a	7.22	c	1.57	a	1.45	a
	F	***		***		***		**		***	
Treatment x Year		*		ns		ns		ns		ns	

[1] ns, *, **, *** indicate not significant and statistically significant at the 0.05, 0.01, and 0.001 levels, respectively. Values followed by the same letters do not differ significantly.

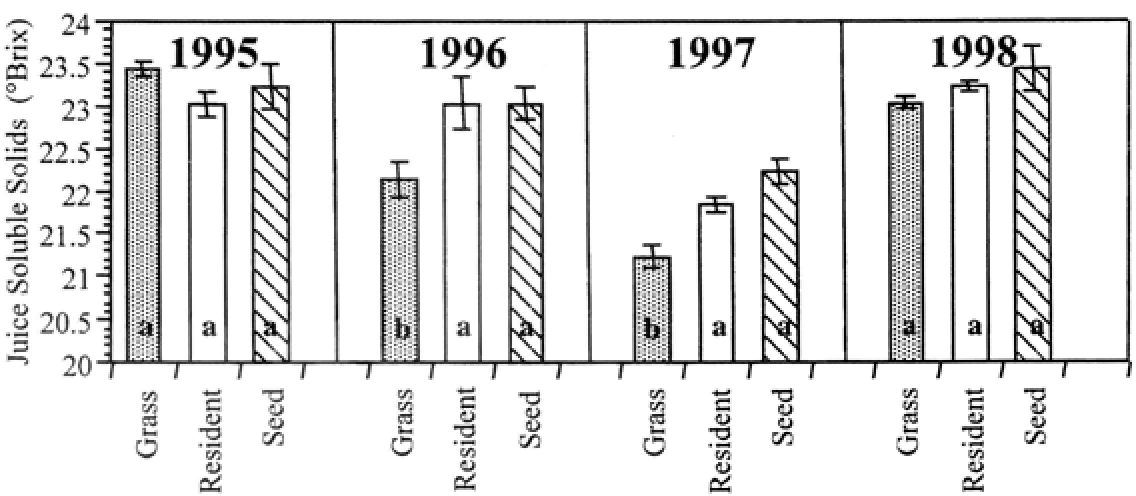

Figure 2: Effect of green cover treatment on juice soluble solids of Pinot noir grapevines during the past four seasons.

CONCLUSIONS

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 benefit of better fruit quality.

More diverse green 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 green covers may contribute to ecological stability and be less competitive to the grapevine.

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