Preplant Cover Crops Affect Weed and Vine Growth in First-year Vineyards

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Abstract. Use of in-row cover crops for weed management in first-year vineyards was investigated in two studies. In the first study, rye (*Secale cereal* L. 'Wheeler') was fall-planted, overwintered, then managed by three methods before vine planting. Rye was either herbicide-desiccated with glyphosate and left on the surface as a mulch, mowed, or incorporated into the soil (cultivated). Weed density and growth of grapevines (*Vitis* spp.) were evaluated. Herbicide desiccation was superior to the other methods for weed suppression, with weed densities 3 to 8 times lower than for mowed or cultivated plots. Vine growth was similar among treatments, but the trend was for more shoot growth with lower weed density. In a second study, four cover crops, rye, wheat (*Triticum aestivum* L. 'Cardinal'), oats (*Avena sativa* L. 'Ogle'), and hairy vetch (*Vicia villosa* Roth), were compared. Wheat and rye were fall- and spring-planted, and oats and vetch were spring-planted, then desiccated with herbicides (glyphosate or sethoxydim) after vine planting and compared to weed-free and weedy control plots for weed suppression and grapevine growth. Cover crops provided 27% to 95% reduction in weed biomass compared to weedy control plots. Total vine dry mass was highest in weed-free control plots, was reduced 54% to 77% in the cover crop plots, and was reduced 81% in the weedy control. Fall-planted wheat and rye and spring-planted rye plots produced the highest vine dry mass among cover crop treatments. Spring-planted rye provided the best combination of weed suppression and vine growth. Chemical names used: *N*-(phosphonomethyl) glycine (glyphosate isopropylamine salt); 2-[1-(ethoxyimino)butyl]-5-[2-(ethylthio)propyl]-3-hydroxy-2-cyclohexen-1-one (sethoxydim).

Cover crops are useful in a variety of cropping systems for improving weed control, increasing organic matter, improving soil structure, reducing soil erosion, and enhancing water penetration and retention. Cover crop use for reducing soil erosion (Khan et al., 1988) is especially important in vineyards since many are planted on sloping land highly susceptible to erosion. Cover crops also influence soil moisture and the soil microclimate, which has implications on insect and pathogen populations (Bugg, 1992; Norris, 1986). The use of cover crops to suppress weeds is being evaluated in many horticultural crops as demands for reduced chemical use, lack of available materials for minor use crops, and concern over groundwater contamination have reduced the options available to the producer

(Wallace and Bellinder, 1992). Living rye and its residues have provided good suppression of a variety of weeds (Barnes et al., 1986). Similarly, residues of sorghum [*Sorghum bicolor* (L.) Moench], barley (*Hordeum vulgare* L.), wheat, and oats can provide exceptional suppression of several weed species (Putnam and Tang, 1986). Putnam et al. (1986) studied a variety of crops and systems to suppress weed growth and found the most successful approach was to grow cover crops of rye, wheat, sorghum, or barley to a height of 40 to 50 cm, desiccate the crops by contact herbicides or freezing, and allow their residues to remain on the soil surface. Often, up to 95% control of important weed species could be obtained for 30 to 60 d following desiccation of the cover crop.

Though most studies on using cover crops to suppress weeds have been with vegetables, some work has been done on strawberries (*Fragaria xananassa* Duch.) (Smeda and Putnam, 1988) and other perennial fruit crops (Putnam, 1986; Putnam et al., 1986). Orchard floor management strategies, including cover crops and mulches, and their effects on tree growth and soil characteristics have been reviewed by Hogue and Neilsen (1987) and Skroch and Shribbs (1986). Welker and Glenn (1988) showed young peach trees grew better and yielded more when trees were planted into a killed sod system, compared to cultivation, mowing, or herbicide management systems. Establishing a living sod before planting the trees, and then killing the sod with herbicides,

prevented the depletion of soil organic matter and increased water infiltration rates, aggregate stability, macroporosity, and microbial respiration rates compared to conventional systems.

Most cover crop research in grapes has focused on row middle management, rather than in-row management. The competitive effects of permanent sod row middles on grapevine growth and productivity have been shown (Pool et al., 1990; Shaulis and Steele, 1969; Tan and Crabtree, 1990). Mulching as a method of row middle management has been invested in grapes (Pool et al., 1990). In a vineyard with shallow soil, vines grown with mulched row middles had a significantly greater increase in cane pruning weight than did vines grown with sod middles. Growth suppression of sod-managed vines occurred only in relatively dry years. Increases in root, shoot, and berry production by the use of organic or plastic mulches in the row have been reported. In a study comparing in-row soil surface management, yield of first crop vines grown in plastic mulched plots was nearly three times the yield of plots with grass sod (Stevenson et al., 1986). In-row mowed grass sod reduced yields and led to pruning weights that were 2 to 3 times less than with herbicide or plastic mulches. The increased growth of mulched vines has been attributed to weed control and improvements in soil physical conditions (Richards, 1983). The creation of favorable soil conditions under mulch, together with the absence of tillage, allows shallow root development. Straw mulch encourages shallow root development in grapevines (Van Huyssteen and Weber, 1980).

Weed control is one of the most important cultural practices determining vine growth during the establishment of vineyards (Zabadal and Dittmer, 1994). Failure to control weeds during vineyard establishment results in reduced vine growth and a delay of 1 year or more until vines reach full production. Relatively few preemergence herbicides options are available for use during the vineyard establishment year and most give only short-term control, especially under high rainfall conditions prevalent during the growing season in the midwestern United States.

Use of cover crops for weed suppression during the establishment year may be feasible in vineyards because cover crops are an integral part of site preparation for vineyards. Traditional methods of vineyard establishment include soil preparation a year before vine planting and establishment of a fall cover crop that is incorporated into the soil by cultivation before vine planting to increase the organic matter content of the soil and improve vine establishment and growth. An alternative to preplant cultivation would be to desiccate the cover crop in the vine row and leave the cover crop residue on the soil surface as a mulch, potentially reducing the need for a soil herbicide application after vine planting. The objective of this study was to evaluate the potential use of herbicide-desiccated cover crops for weed suppression in the vine row during the vineyard establishment year.

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Materials and Methods

Cover crop elimination method. The first study evaluated methods of handling a fall-planted rye cover crop before vineyard establishment. Mowing, incorporation by cultivation, and herbicide desiccation were compared for effects on weed density and total subsequent vine shoot growth. In Sept. 1991, 'Wheeler' rye was drilled at 112 kg-ha⁻¹ into Crosby-Miami complex silt loam soils (Aeric Epiaqualfs-Typic Hapludalfs), overwintered, and on 5 May 1992 the following treatments were established for rye: mowed, incorporated into the soil by cultivation, or desiccated with glyphosate with a.i. at 0.84 kg-ha⁻¹. Plots were established in rows 3.8 m apart and the managed area of each plot was 1.2 m wide × 7.3 m long. Cuttings of 'Seyval' and 'Vignoles' were rooted in the greenhouse under mist, potted in 3.8-L containers, and grown for 4 weeks. Three vines were planted into each plot on 5 June 1992 at a spacing of 2.3 m. Vines were pruned to a single shoot that was supported by tying to bamboo stakes. The area between the rows was mowed as needed. Nitrogen was band-applied at 74 kg-ha⁻¹ actual N in the form of NH₄NO₃ 4 weeks after planting. Pest management practices were followed as recommended for Indiana (Hayden et al., 1992).

The design was a split-plot with grape cultivars Seyval and Vignoles being the main plots and three cover crop management schemes being the subplots. Treatments were replicated four times. Weed density was measured 8 weeks after plot establishment from two random 0.09-m² areas from the managed plot area. Total shoot growth of each vine was measured after leaf fall on 5 Nov. 1992.

Cover crop comparison. A second study was conducted to compare four cover crops: wheat, rye, oats, and hairy vetch. The design was a randomized complete block with eight treatments and five replications. Plots were laid out in rows 3.8 m apart and the managed area was 1.2 m wide × 6.1 m long. In-row soil management treatments were fall-planted 'Wheeler' rye, spring-planted 'Wheeler' rye, fall-planted 'Cardinal' wheat, spring-planted 'Cardinal' wheat, spring-planted hairy vetch, spring-planted 'Ogle' oats, weed-free bare ground (manually weeded as needed), and weedy bare ground (with no weeding or physical disturbance of the soil). The entire field was cultivated in the fall, and fall-planted rye and wheat plots were drilled on 1 Oct. 1993. The following spring, plots for spring-planted rye, wheat, hairy vetch, and oats were cultivated and cover crops were drilled on 24 Mar. 1994. The weedy control plots were not cultivated before establishment of grapevines. The weed-free control plots were cultivated before planting vines and as needed to provide complete weed control during the growing season. All cover crops were drilled at 112 kg-ha⁻¹. Soil type in the plot was Starks-Fincastle complex silt loam (Aeric Epiaqualfs). Three 1-year-old dormant rooted cuttings of 'Steuben' (*Vitis labruscana* Bailey) were planted 1.2 m apart into each plot on 17 May 1994. Vines

were pruned to two buds and the shoots were supported by tying to bamboo stakes. Nitrogen was band-applied at 74 kg-ha⁻¹ actual N in the form of NH₄NO₃ 4 weeks after planting. Pest management practices were followed as recommended for Indiana (Hayden et al., 1992).

Cover crops were desiccated with post-emergent herbicides on 2 June 1994, ≈2 weeks after vine planting. Cereal cover crops were treated (a.i.) with sethoxydim + crop oil (0.42 kg-ha⁻¹ + 2.72 L-ha⁻¹) and vetch was treated with glyphosate at a.i. 0.84 kg-ha⁻¹ by wiper application to avoid injury to grapevines. Plots received ≥25.4 mm of water per week through rainfall or overhead irrigation throughout the growing season. Cover crop biomass was sampled 2 weeks, and weed biomass was sampled 2 and 8 weeks after desiccation by collecting the cover crop and weeds in a 0.37-m² random area in each plot. Weed biomass data were summed from both collection dates before analysis. Weed identification and counts were made when samples were collected. Weed samples were dried at 50 °C and weighed. At the end of the growing season, vines were destructively sampled for leaf area and count, shoot length and count, and top growth and root system dry mass. Leaf area was measured by passing the detached leaves through a LI-3100 area meter. (LI-COR, Lincoln, Nebr.). After measurement, tissues were dried at 50 °C and weighed.

Results and Discussion

Cover crop elimination method. Herbicide-desiccated rye provided better weed suppression than when either mowed or incorporated (Table 1). Weed densities in the desiccated rye were 3 to 4 times lower than in the incorporated rye and 7 to 8 times lower than in the mowed rye 8 weeks after plot establishment. Weed density was high in the mowed and incorporated rye, likely due to the less complete soil coverage by the rye biomass and disturbance of the soil when rye was incorporated. The rye was dead after all treatments and did not compete with the vines. There were no significant differences in total vine shoot growth among the treatments; however, the trend was of increased shoot growth where weed density was decreased. These results suggest that there is potential for acceptable weed control and vine growth during the first year of vineyard establishment from herbi-

cide-desiccated cover crop left on the soil surface as a continuous mulch layer.

Cover crop comparison—Weed and cover crop biomass. Weed biomass was reduced by 27% to 95% by cover crops compared to the weedy control (Table 2). Spring-planted cereals resulted in the best weed suppression. Among these, oats produced the highest cover crop biomass. The cultivars of rye and wheat used were winter types that did not tiller after spring planting, while the oat cultivar was a spring type that did tiller, resulting in increased cover crop biomass. Fall-planted wheat produced more than 3 times as much cover crop biomass as spring-planted wheat, and fall-planted rye produced more than 2 times as much as spring-planted rye. However, weed biomass was 8 times higher in fall-planted wheat than spring-planted wheat and 4 times higher in fall-planted rye than spring-planted rye. This apparent anomaly of having the best weed suppression in plots with the lowest cover crop biomass can be partially explained by the differential effects of the postemergent herbicides on the fall- and spring-planted cover crops. Though the intent was to completely kill the cover crops by application of sethoxydim, spring-planted cereals were only suppressed, but the fall-planted cereals were completely killed. Spring-planted cereals remained alive for several weeks, but grew very little and slowly died over the course of the summer. Because the spring-planted cover crops remained alive, they likely continued to exert competitive and alleopathic effects, resulting in almost complete suppression of weeds. The suppressed spring-planted cereals resulted in weed biomass that was 82% to 95% less than the weedy control. Similarly, Barnes and Putnam (1983) found that spring-planted living rye reduced weed biomass by 93% over plots without rye.

Most of the differences in weed biomass between fall-planted wheat and rye and spring-planted wheat and rye were due to the emergence of summer grasses in fall-planted plots, specifically barnyardgrass [*Echinochloa crusgalli* (L.) Beauv.] and giant foxtail (*Setaria faberi* Herrm.). No follow-up weed control was performed in this experiment, so once weeds became established, they grew quite large. Weed suppression was poor in the fall-planted plots; however, we observed that weeds were suppressed for at least 6 weeks after herbicide desiccation.

Vetch was only suppressed by the initial

Table 1. Effects of management technique for fall-planted rye on weed density and vine shoot growth (1992).

Cover crop elimination method	Total vine shoot growth (cm) ^a		Weeds (no./m ²) ^b	
	Cultivar			
	Seyval	Vignoles	Seyval	Vignoles
Herbicide-desiccation	145	89	27 b	23 c
Incorporation	135	75	84 b	101 b
Mowing	112	74	187 a	181 a
LSD ^c	NS	NS	77.7	67.4

^aMean of three vines per plot, four replications per treatment.

^bBased on the average of two 0.09-m² samples per plot, four replications per treatment.

^cMean separation by LSD at P = 0.05.

Table 2. Vine dry mass, cover crop biomass, and weed biomass in cover crop treatments (1994).

Treatment	Dry biomass				
	Total vine ²		Cover crop ³		Weed ⁴
	(g)	% of weedy control	(g·m ⁻²)	(g·m ⁻²)	% of weedy control
Weed-free control	131 a	527	na ⁵	0	0
Spring rye	60 b	241	97 c	37 c	18
Fall wheat	58 b	232	282 a	89 bc	44
Fall rye	53 b	214	241 ab	149 ab	73
Spring wheat	42 bc	167	83 c	11 c	5
Spring oats	39 bc	156	212 b	15 c	8
Vetch	30 c	122	108 c	71 bc	35
Weedy control	25 c	100	na ⁵	203 a	100
LSD ⁶	23.3		69.1	86.9	

²Total vine dry mass was collected at the end of growing season, 20 weeks after planting. Mean of three vines per plot, five replications per treatment.

³Cover crop biomass samples were collected 2 weeks after herbicide desiccation from a 0.37-m² area within each plot. Mean of five replications.

⁴Weed biomass samples were collected 2 and 8 weeks after herbicide desiccation from a 0.37-m² area within each plot and summed for analysis. Mean of five replications.

⁵Not applicable because no cover crop was established in the weed-free control or weedy control plots.

⁶Mean separation by LSD at $P = 0.05$.

application of glyphosate and a second application was necessary to achieve complete kill. Similar results of incomplete cover crop control have been reported (Wallace and Bellinder, 1992). Vetch was moderately effective at reducing weed biomass, resulting in a 65% reduction over the weedy control.

Predominant weed species differed among cover crops. Grasses comprised 47% of the weeds in fall-planted cereals, 24% in the spring-planted cereals, 7% in the vetch, and 6% in the weedy control (detailed data not shown). Fall-planted rye and wheat suppressed broadleaf weeds to a greater extent than grasses, especially late-season grasses, such as barnyard grass and giant foxtail. This finding is in agreement with previous studies where rye residues suppressed annual dicotyledonous weeds better than annual grasses and had little effect on perennial weeds (Barnes and Putnam, 1983; Masiunas et al., 1995; Putnam and DeFrank, 1983). This difference could be an advantage in a grape production system because grasses can be controlled in the row more easily than broadleaves by using grass-specific herbicides after vines are planted.

Cover crop comparison—Vine growth. Total vine dry mass was highest in the weed-free control, least in the weedy control, and intermediate in the cover crop plots (Table 2). Spring-planted rye, fall-planted rye, and fall-

planted wheat resulted in the highest total vine dry mass among the cover crops, which was more than twice that in the weedy control. With the exception of spring-planted rye, total vine dry mass in spring-planted cover crops was similar to that of the weedy control. In the case of spring-planted rye, oats, and wheat, the reduction in total vine dry mass compared to the weed-free control was probably due to allelopathy and competition. However, allelopathy may have been more important because the suppressed cover crops were very low in vigor, little weed growth occurred, and water was not limiting since plots received irrigation or rainfall weekly. Reduction in vine dry mass in fall-planted wheat and rye, and vetch plots was most likely due to weed competition, because the cover crop was killed by herbicide and weed biomass was relatively high.

Grapevines in cover-cropped plots grew less than in the weed-free control in terms of total leaf area, leaves per vine, shoot length, and top and root dry mass (Table 3). Average leaf size did not differ among treatments, but differences occurred for all other variables measured. Vines in the weed-free control had more leaves, longer shoots, and more top and root dry mass than all other treatments. Reduction in vine root dry mass and, to a lesser extent, top dry mass in the cover-cropped plots

compared to the weed-free control is of concern regarding using this system during vineyard establishment. Although vines in the fall-planted wheat and rye and spring-planted rye had more than twice the total vine dry mass than those in the weedy control, there was still a 57% or greater reduction in root dry mass in cover crop plots compared to weed-free plots. These same treatments showed less reduction in leaf area (23% to 43%) than in top dry mass (46% to 53%) and root dry mass (57% to 70%). For the other cover crop treatments, the percentage of reduction in vine leaf area closely matched the reduction in top and root dry mass.

The vine top : root (dry mass) ratio differed among the cover crop plots. Values of the top : root ratio for grapevines vary and are usually only reported for young plants that are relatively easy to measure (Richards, 1983). Bravdo et al. (1972) found that 1-year-old rooted cuttings of eight grapevine cultivars had top : root dry mass ratios ranging from 0.70 to 1.08 after one season of growth. Most of the ratios in our study fall within that range. Vines in fall-planted rye and wheat plots had the highest top : root ratios while vines in the weedy control had the lowest. Many environmental factors are known to affect top : root ratios (Boote, 1976). Generally, when limitations occur in the root environment, plant growth and the top : root ratio decline, while limitations in the aerial environment usually result in reduced growth and an increase in top : root ratio. In grapevines, reduced water supply (Hofacker, 1977), low fertility levels (Erlenwein, 1965), and low root temperatures (Woodham and Alexander, 1966) decreased growth and top : root ratios, while low light intensities decreased growth but increased top : root ratios (Buttrose, 1969). The increased top : root ratios in vines in the fall-planted rye and wheat likely resulted from shading by the large summer grasses that became established in the plots midway through the season. Vines in the weedy control plots were likely affected by soil and aerial factors resulting from competition by weeds for water, nutrients, and light, resulting in low top : root ratios.

Reduced vine growth in this study is likely due to a combination of competition and allelopathy. As with weed suppression, allelopathy may have been more important than com-

Table 3. Effects of cover crop treatments on vine growth² (1994).

Treatment	Vine growth measurements						
	Leaf area/vine (cm ²)	Leaves/vine (no.)	Shoot length/ vine ³		Dry mass		
			Mean leaf size (cm ²)	(cm)	Top (g)	Root (g)	Top : root
Weed-free control	4142 a	128 a	33	371 a	59 a	73 a	0.81
Spring rye	2548 bc	97 b	27	273 b	29 b-d	32 b	0.91
Fall rye	2433 b-d	77 bc	30	270 b	32 b	22 b-d	1.45
Fall wheat	2371 b-d	68 bc	36	281 ab	29 bc	28 bc	1.04
Spring oats	1595 c-e	54 cd	29	166 c	17 de	22 b-d	0.80
Spring wheat	1404 de	58 c	24	156 c	18 c-e	23 b-d	0.79
Vetch	1155 e	47 cd	26	121 c	13 e	18 cd	0.71
Weedy control	807 e	26 d	29	110 c	9 e	16 d	0.60
LSD ⁴	1133	31	NS	96	12.1	11.2	

²Vine growth measurements are based on three vines per plot, five replications per treatment.

³Sum of main shoots and laterals.

⁴Mean separation by LSD at $P = 0.05$.

petition with the spring-planted wheat and oats, which had very low weed biomass, yet total vine dry mass that did not differ from the weedy control.

Weed competition and allelopathic effects of cover crops may represent stresses on vines similar to crop load. Reductions in total leaf area and top and root dry mass of vines in this study were very similar to reported responses of vines to crop load. Growth of grapevines decreases as crop load increases (Kaps and Cahoon, 1989; Weaver and Pool, 1969) and crop reductions are recommended to increase vine size. Edson et al. (1995) found that total leaf area, leaf, shoot, and root dry mass of vines was inversely related to crop load. Root dry mass was decreased up to 35% by high crop loads.

Some reduction in vine growth can be expected from preemergent herbicide application. Zabadal and Dittmer (1993) studied the effects of various herbicides on growth of 1-year-old 'Niagara' grapevines and found a 25% to 82% reduction in shoot dry mass and a 32% to 75% reduction in root dry mass in the herbicide-treated plots compared to manually weeded control. Part, but not all, of the reduction in vine growth could be attributed to weed competition, suggesting that herbicides were responsible for some of the reduction.

It is uncertain whether control of summer grasses in the fall-planted rye and wheat treatments would have reduced the negative effects on vine growth. Since the growing season lasted 18 to 20 weeks, vines were in competition with these weeds for more than half the season. Though the plots received ≥ 25.4 mm water per week through rainfall or irrigation, the water provided was likely not sufficient to overcome the competitive effects of vigorous grass growth and the associated reduced light intensities in those plots. We assume that, if follow-up weed control had been applied, vine growth would have been less affected. However, our data are not sufficient to conclude that the degree of vine growth in the fall-planted rye and wheat plots would have been similar to that in the weed-free controls if summer grasses had been controlled.

The use of cover crops for early season weed suppression in establishment-year vineyards appears to have promise based on these results. Though vine growth was reduced in cover cropped plots compared to the weed-free control, complete weed control (as was practiced in the weed-free control plots) is seldom achieved in commercial plantings. A typical weed management program in commercial plantings would include pre- and postemergent herbicides and manual weeding. Some vine growth suppression can be expected from preemergent herbicides and weed competition. Weed control represents a considerable expense in labor and materials.

Use of cover crops for weed suppression likely would reduce labor expenses and chemical inputs. A system to use the weed suppressive capabilities of spring- or fall-planted rye or wheat combined with measures to minimize inhibition of vine growth could potentially provide season-long weed control and vine growth similar to other weed management programs. Proper management of the cover crop would be necessary as well as some follow-up weed control during the growing season to ensure adequate vine growth. This approach to weed suppression would fit in well with the standard cultural practices for vineyard establishment. Cover crop suppression of weeds may be most useful in mature vineyards where vine competition is of less concern, or is desirable. Research into the potential of cover crops for weed suppression in mature vineyards is warranted.

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