COVER CROPS FOR NITROGEN MANAGEMENT IN IRRIGATED CROPPING SYSTEM

Joan R. Davenport, Washington State University, jdavenp@wsu.edu
24106 N. Bunn Road, Prosser, WA 99350, 509-786-9384
Kyle Bair, Soil Test Farm Consultants, Moses Lake, WA
David Granastein, Washington State University, Wenatchee, WA

ABSTRACT

In perennial fruit cropping systems, the inter-row offers on opportunity to grow a cover crop that then can be used to supply nitrogen (N) to the fruit crop. We conducted research in both Concord grape and Gala apple to evaluate the potential of cover crops to supply N to the crop. Based on continuous monitoring of plant available NO_3-N by using PRS^{TM} ion exchange resin probes, we found that in Concord grape, while both hairy vetch and yellow sweet clover did not release quite as much N as a commercial synthetic fertilizer, the total release was well timed with crop demand. For Concord, the plants were mowed slightly prior to bloom. In general, fall planting of hairy vetch was superior to other legume management systems. In Gala apple, a different system of management was used where the legumes were allowed to grow and were mowed with the clippings being blown into the tree row. Of the four legumes studies, alfalfa had the highest amount of N plus N released. However, data from the 2010 study, where the legumes had one additional year of establishment, indicated that the lower growing kura clover had increased its plant biomass and possibly may be a better long term legume for the mow and blow system.

INTRODUCTION AND OBJECTIVES

When growing perennial fruit crops, the inter row area offers an opportunity to plant a leguminous cover crop which can then be used as a nitrogen (N) supply for the fruit crop. We have tested several legumes as inter row crops in both Concord grape and apple as potential N sources. In Concord, yellow sweet clover and hairy vetch were compared with a wheat cover with either no N or an organic or synthetic N source. In apple, an array of legumes were established and used in a "mow and blow" strategy. The objectives of these studies is to determine a management system to "grow your own N" for perennial fruit crops.

MATERIALS AND METHODS

Concord Grape Study:

To determine the potential of yellow sweet clover and hairy vetch to provide N in organic grape production, two Concord vineyards near Prosser, WA from 2003 to 2005. The two vineyards are referred to as R and C for the research and commercial sites, respectively. Since the commercial farm was certified organic, synthetic fertilizer comparisons were made on the research farm.

Plots established on both vineyards were 3 vine rows by 8 vines in a Latin square design with 4 or 6 replicates of each treatment. Treatments in the commercial vineyard consist of yellow sweet clover and hairy vetch in either a fall (18-30 August) or spring (30 June—18 July) plant, hairy vetch with half planted in the fall and half in the spring, and a wheat or rye (referred to as small grains) cover with 100 lbs $N \cdot A^{-1}$ applied as blood meal. Treatments in the research vineyard include both legume cover crops planted in the fall, 100 $N \cdot A^{-1}$ as urea, and a 0 N control. Control and N fertilized treatments in both vineyards were under a wheat or rye cover from late fall until early spring, a common practice in the Yakima Valley region of Washington to prevent topsoil losses from wind erosion and supply organic residues back to the soil (R. Stevens, personal communication). Table 1 summarizes which treatments apply to the research and commercial vineyards. Cover crop incorporation took place at bloom for all treatments. Bloom occurred on May 30, 2004 and 3 June, 2005.

To measure soluble N release from yellow sweet clover and hairy vetch decomposition after incorporation, plant root simulator (PRS™) probes (Western Ag Innovations, Saskatoon, Canada) were used in conjunction with weekly soil samples. Anion (for NO_3-N) specific probes were placed below the soil surface to track soluble N (Quian and Schoenau, 2000). PRS probes were exchanged weekly for the first 4 weeks after incorporation of cover crops and then bi-weekly for the duration of the sampling period. Concentrations extracted from the probes represent the availability of soluble N to an area of root over a week *in situ*. Probes were extracted with 20 mL of 0.5 M hydrochloric acid (HCl) (Quian et al., 1992) and analyzed colormetrically for NO_3-N (Environmental Protection Agency, 1984b) using an EasyChem Flow Analyzer (Systea Scientific LLC, Oak Brook, IL).

Representative soil samples were collected at 0-15 and 15-30 cm depths from each plot in conjunction with PRS exchanges. Soil samples were allowed to air-dry and were ground to pass a 2 mm sieve. Soluble NH_4-N and NO_3-N were extracted with 2.0 N potassium chloride (KCl, Mulvaney, 1996) and analyzed colormetrically with an EasyChem Flow Analyzer. Extract samples were frozen for storage and thawed prior to analysis.

Statistical analysis of the data was performed using the PROC GLM of PC SAS (SAS Institute, Cary, NC).

Gala Apple Study:

Four different perennial legumes (alfalfa, birdsfoot trefoil, ladino clover, kura clover) were direct seeded in a four-foot wide strip treated before planting with herbicide in the middle of the drive alleys in a commercial orchard in Quincy, WA. Full length rows were planted, and a portion of each row was left unsprayed to determine the value of the competition reduction. The established grass cover crop control was included as a fifth treatment. The design is a randomized complete block with four replicates. Mow and blow operations were conducted on May 29, July 3, August 20, and October 1, 2009. The study was repeated in 2010 (data not yet available).

Percent cover in the alley was determined three times using the point intersect method to separate cover crop, weeds, and bare ground. A biomass sample of each cover crop was collected just prior to mowing, dried, weighed, and analyzed for total N (Yeomans and Bremner, 1991). Mowing was done as a 'mow and blow' system to deliver the biomass to the tree row. Once mowing started, soil samples were collected biweekly from the top foot of soil and analyzed for NO_3-N (Mulvaney, 1996). Beginning in July, Plant Root Simulator (PRS™) probes were placed in the tree row to measure N mineralization for two-week periods consistent with the soil sampling intervals, with analysis as described above. Soil nitrogen status was evaluated with an early season and post harvest sample (3-ft depth, in 1-ft increments) for available N.

Tree nitrogen status was monitored with a leaf sample for total N collected in July and August. Tree canopy volume was also measured as another indicator of tree vigor. Tissue samples were analyzed using dry combustion (Yeomans and Bremner, 1991).

RESULTS AND DISCUSSION

In both studies, a combination of soil sampling and PRS probes were used to assess nitrogen availability. While soil sample analysis shows us point in time measurement, the PRS integrates N availability over time. In both studies, the soil test results supported the findings from the PRS probes, thus, in this document, only the PRS results will be presented. Information on the Concord grape study soil test results is available in Bair et al., 2008.

In grape, treatment analysis was evaluated across the critical growth stages of the plant to reduce the large number of data points. These stages were pre-bloom (PB), bloom to veraison (BTV), and post-veraison (PV), where veraison is defined as the onset of grape ripening. There were significant differences in PRS NO_3-N by year, treatment and time of season.

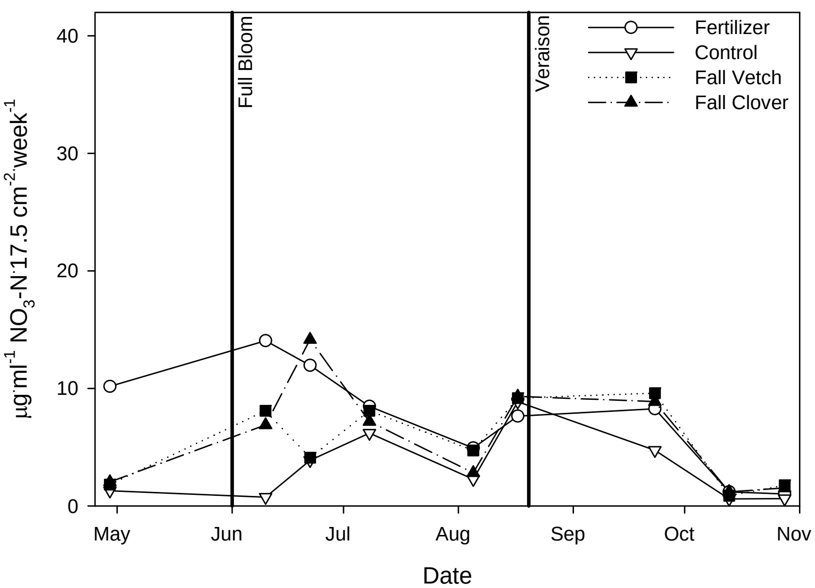

Figure 1. Average PRS NO_3-N collected during 2004 at the R vineyard. Fall refers to the time of cover crop planting. Bold vertical lines correspond to the dates of full bloom and veraison.

In 2004, PRS NO_3-N patterns were only significantly different with cover crop at the R vineyard (Fig. 1). Statistical analysis of data (Table 1) showed that at PB the fertilizer treatment was statistically the highest, which is expected because the fertilizer was applied in early April. From BTV fertilizer and clover treatments were significantly higher than the control, while the vetch was intermediate. Elevated levels of PRS NO_3-N occurred for all treatments at this vineyard during the critical N demand period of BTV. Since the PRS levels for all treatments remained high during PB and then BTV decreased dramatically, movement of NO_3-N from vine or weed uptake, leaching, immobilization, or gaseous losses was likely occurring. Because the decreases in PRS NO_3-N approximately coincided with the time of peak plant N demand plant uptake is a likely pathway, however, other pathways cannot be entirely excluded.

As a whole, 2005 treatments at both sites had significantly higher accumulations of PRS NO_3-N than in 2004 from BTV and PV (Table 1), with the exception of the synthetic fertilizer plots at the R vineyard. Because cover crop N content remained constant, increases in soluble N were directly related to the higher production of cover biomass from 2004 to 2005. Table 2 shows how significantly biomass contributes to the total amount of N supplied. C vineyard PRS NO_3-N concentrations in 2005 were significantly higher in the blood meal treatment from BTV than legume treatments except for the vetch-half/half, which was intermediate. Legume treatments were not statistically different from one another. PV concentrations returned to low levels with few differences by treatment. Blood meal resulted in the highest sustained levels of PRS NO_3-N in 2005; this was not true in 2004, implying that year to year variability in plant available N from blood meal application can be significant. Results of the corresponding data from the R vineyard in 2005 show that both legume treatments were significantly higher than the control during BTV, however, the legumes were not different from each other (Table 1).

Table 1. Mean PRS NO_3-N concentrations in 2004 and 2005 at R and C sites during time designations of pre-bloom (PB), bloom to veraison (BTV), and post-veraison (PV). Means with different letters in the same column and site are significantly different (□=0.05). *P*-values are given for each year and time designation combination.

Year	Site	Treatment	PB	BTV	PV
2004			$\mu g \cdot ml^{-1}$ NO_3-N $\cdot$ 17.5 $cm^{-2} \cdot week^{-1}$		
	R	Fertilizer	10.17 a	10.05 a	3.50 a
		Control	1.29 b	4.39 b	1.98 a
		Fall Vetch	1.82 b	6.84 ab	4.08 a
		Fall Clover	2.05 b	8.08 a	3.87 a
	C	Blood meal	5.78 a	2.95 a	-
		Fall Vetch	9.25 a	8.61 a	1.69 a
		Fall Clover	9.69 a	3.86 a	2.76 a
	P-value		<0.001	0.069	0.157
2005					
	R	Fertilizer	-	9.34 ab	6.45 a
		Control	-	6.00 b	5.61 a
		Fall Vetch	-	12.25 a	5.32 a
		Fall Clover	-	12.65 a	4.65 a
	C	Blood meal	-	24.81 a	8.17 a
		Spring Vetch	-	13.57 b	8.27 a
		Fall Vetch	-	12.69 b	5.34 ab
		Vetch	-	19.23 ab	5.95 ab
		Spring Clover	-	13.84 b	5.96 ab
		Fall Clover	-	15.62 b	4.50 b
	P-value			<0.001	0.137

In apple, monitoring of soil nitrate nitrogen with PRS probes showed a slight significant difference in N with cover treatment but not with date, likely due to the relatively low number of sampling dates. Overall, Alfalfa showed the greatest seasonal release of N, with Ladino and Trefoil the next highest, Kura the lowest of the legumes but showing more N release than the grass treatment (Table 2). This, coupled with the soil nitrate data above, indicates that alfalfa likely releases a more consistent supply of N in orchards with this type of management.

Table 2: Average PRS nitrogen across all sampling dates for different covers as N sources in an orchard (significant at <0.10).

Cover	PRS NO_3-N (ppm)
Alfalfa	251
Ladino clover	173
Trefoil	179
Kura clover	132
Grass	103

Cover crop biomass over the growing season (4 mowings) was greatest for alfalfa, similar for ladino clover, trefoil, and grass, and lowest for kura clover (Fig. 2). Kura clover did increase its biomass as the season progressed. Total biomass was similar between sprayed and unsprayed areas, but sprayed areas had a higher percentage of legume (Table 3), which boosted the total contribution of nitrogen due to the higher N content in the legumes (Table 4). Estimated seasonal total N (lbs/A) in the cover crop biomass was 48 (alfalfa), 28 (ladino clover), 29 (trefoil), 15 (kura clover), and 15 (grass control).

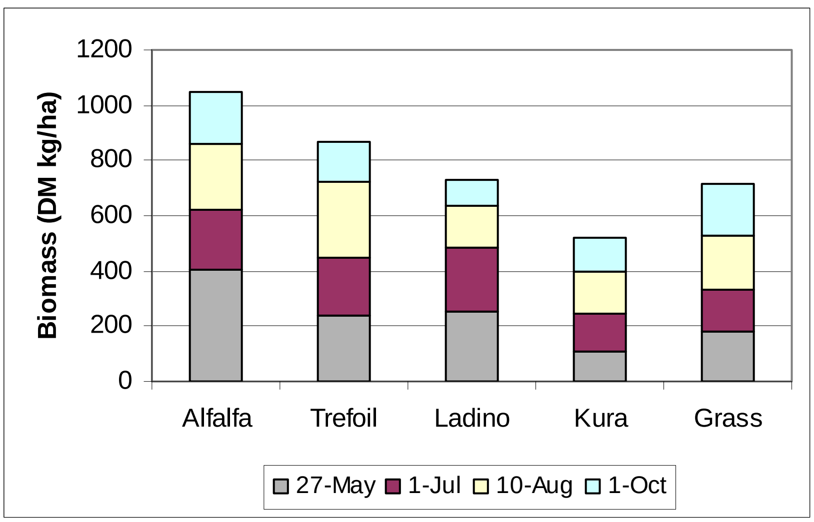

Figure 2. Cover crop biomass (dry matter) for each mowing in 2009. (1 kg/ha = 0.9 lbs/A)

This study was continued in 2010 and biomass results indicate that the ladino clover stand declined while the trefoil and kura clover biomass increased (data not given). These species need more years of evaluation in an orchard setting to determine their longevity.

Table 3. Effect of pre-seeding treatment (with or without herbicide suppression) on total and legume biomass dry matter.

	Sum of biomass DM 8/08, 7/09, 8/09 cuttings		Legume biomass only, 7/09	
	Sprayed	*Unsprayed*	*Sprayed*	*Unsprayed*
	- - - - - - - Dry matter (kg/ha) - - - - - - -			
Alfalfa	759 a	685 a	157 a	105 b
Ladino	701 a	719 a	191 a	131 b
Trefoil	783 a	716 a	141 a	74 b
Kura	476 a	486 a	56 a	18 a

Table 4. Cover crop biomass tissue N concentration and C:N.

	% N	C:N
Alfalfa	4.06	10.6
Ladino	3.77	11.2
Trefoil	3.36	13.0
Kura	2.83	14.9
Grass	2.15	18.8
Non-legume	2.32	17.7

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Program Chair:
Robert Flynn, Program Chair
New Mexico State University
67 E Four Dinkus Road
Artesia-NM 88210
(575) 748-1228
rflynn@nmsu.edu

Coordinator:
Phyllis Pates
International Plant Nutrition Institute
2301 Research Park Way, Suite 126
Brookings, SD 57006
(605) 692-6280
ppates@ipni.net