WTFRC Project # AH-03-309 Final Report

Project title: **Influences of selected mulches and soil amendments on dynamics of nitrogen and phosphorus availability in the apple root zone**

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OBJECTIVES:

I: Determine rates of decomposition and release of N and P from selected composts.
II: Determine effects of organic mulches and irrigation systems on nitrogen and phosphorus availability and nematode indicators of nutrient fluxes in underlying soil.
III: Determine effects of surface-applied organic mulches and irrigation systems on populations of the root lesion nematode, *Pratylenchus penetrans.*

SIGNIFICANT FINDINGS

- **Rates of decomposition, and release of N and P, vary substantially among composts.**
- **Release of N from composts can be predicted and compost application rates should be adjusted to attain desired release of N during the growing season.**
- **Composts, biosolids and manures are generally good sources of P and increase availability of P in underlying soil.**
- **Paper-based mulches (high cellulose-C) decrease availability of N and P.**
- **Nematode indicators of enhanced nutrient fluxes through the decomposition food web were increased by all organic materials including the paper-based mulches.**
- **Nematode indicators of enhanced nutrient fluxes were not correlated with measured availability of N and P, where paper-based mulches were used.**
- **Root-lesion nematode populations develop more rapidly, after fumigation, in untreated soil than in soil under alfalfa hay mulch.**
- **The abundance of fine roots is greater, and number of root-lesion nematodes per gram of root is lower, under mulches than under untreated soil.**

PROGRESS REPORT

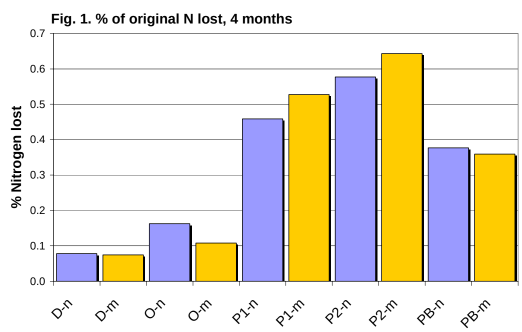
<u>Objective 1: Release of N and P from composts</u>
Approach and Methods: In early May of 2003, a variety of composts (Table 1) were loaded into decomposition tubes which were placed 0-2.5 cm deep in mulched and non-mulched plots in the

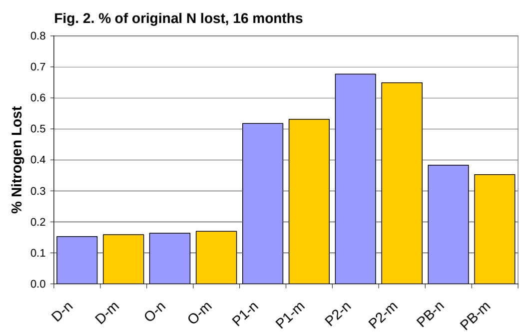
Naches-alfalfa/manure experiment and the Summerland-paper/biosolids experiments. Subsets of the tubes were retrieved in October 2003, May 2004 and October 2004. The dry mass and C, N and P contents of material remaining in the tubes were analyzed, and the loss of C, N and P was calculated in order to estimate the rate at which the materials decompose and release mineral N and P.

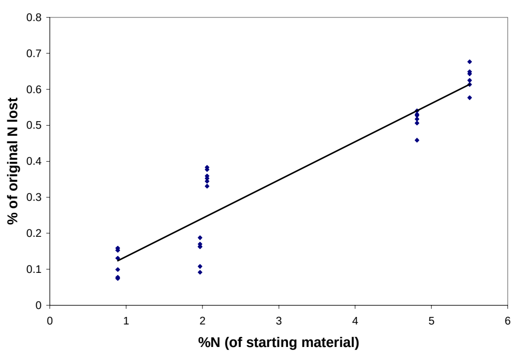
Results and Discussion:

The release of N during the first growing season varied from about 10% (of original N content) for the dairy compost and Ogogrow, to about 60% for one of the poultry manure composts from the Yakima area (Fig. 1). The materials appeared to decompose at similar rates in Summerland and Naches and regardless of whether they were buried under mulches or not (Fig. 1). Estimates of the amount of each material that would have to be applied in order to release 100 lbs of mineral N per acre in the first growing season varied greatly (Table 1). Very little additional release of N occurred during the second growing season (Fig. 2).

Characteristics of the materials tested in this experiment should not be extrapolated to all composts of similar types, as there is likely considerable variation within any given type of compost. Our objective was to use a few contrasting materials to determine if overlying mulches and site (e.g. Naches vs Summerland) had strong effects on decomposition, and then to identify predictors of N release that may be applicable to a variety of compost types. The best single predictor of the first-year release of N from composts is the N content of the starting material (Fig. 3). This indicates that the “fertilizer value” of any given compost may be calculated from its initial N content and a variable percentage release that is, in-turn, a function of the initial N content. Future research by the principal investigator will broaden the scope of this research (i.e. greater number of composts).







Figs. 1 & 2 (above). Percentage of initial nitrogen lost to decomposition during the first growing season (Fig. 1) and end of the second growing season (Fig. 2). D = dairy manure compost, O = Ogogrow, P1 = poultry manure compost 1, P2 = poultry manure compost 2, PB = poultry manure compost from coastal British Columbia; m = under mulch, n = no mulch. **Fig. 3 (left).** Relationship between initial N content and the rate of N release during first year.

Table 1. Selected properties of composts used in the decomposition experiment, and estimates of quantities that would have to be added in order to release 100 lbs of N/acre over the course of one growing season.

	Dairy WA	Hog BC	Poultry WA1	Poultry WA2	Ogogrow BC
C (%)	9	39	37	27	38
N (%)	0.9	2.2	5.4	4.9	2.0
C/N	8.7	40	42	27	19
P (%)	0.55	1.6	1.6	2.2	1.5
K (ppm)	1.79	1.8	1.7	3.9	0.4
Elect. cond. (dS/m)	44	92.8	70	154	n.a.
pH	9.2	5.9	7.0	6.7	n.a.
% N lost in year 1	12	36	51	63	15
Material needed to yield 100 lbs N /acre first year:	**47 t/acre**	**7.0 t/acre**	**2.0 t/acre**	**1.4 t/acre**	**17 t/acre**

<u>Objective II. Indicators of enhanced nutrient fluxes and soil health</u>

Approach and methods:

The primary questions being addressed were: (1) How do combinations organic mulches (surface-applied) and amendments (incorporated before planting) compare with respect to their influences on nutrient availability and indicators of nutrient cycling? (2) How long do the effects persist after application?

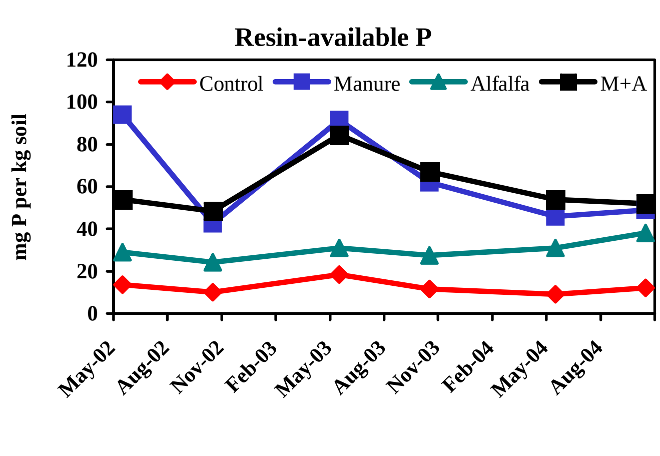
Anion-exchange resin strips were used to perform single-point-in-time laboratory measurements of 'available' P in soil samples taken at multiple sample dates from each set of plots; the same soil samples were used for extraction of nematode indicators of nutrient fluxes and soil health. Anion-exchange resin strips were also incubated in the field (except Naches) to measure the amount of nitrate and phosphate made available over two-week periods in spring (before fertigation) and early summer (after fertigation started). One of our goals is to determine if and how proposed nematode indicators of enhanced nutrient fluxes relate to actual measurements of N and P fluxes and availability.

Results and Discussion:

Alfalfa hay mulch/dairy manure solids (Naches):

Alfalfa hay, dairy manure solids, and a combination of alfalfa hay applied over dairy solids ('M+A') were surface-applied in spring of 2000 during tree establishment. Additional alfalfa has been added yearly since 2000; no additional manure has been applied since establishment.

Manure caused an immediate and substantial increase in resin-available P that persisted through the 2002 and 2003 growing seasons (Fig. 1). By the end of the 2004 growing season, resin-available P in manure treatments was no longer significantly greater than in the alfalfa treatment, but all organic mulch treatment combinations had greater available P than the control.



Nematode indicators of nutrient cycling and soil health were strongly influenced by the treatments (Fig.s 2 a-d), particularly in 2002 and 2003. The nematode Enrichment Index (EI) is indicative of high rates of bacterial production/turnover, and has been correlated with N mineralization in previous studies. The Channel Index (CI) is a measure of the strength of the fungal decomposition pathway relative to bacterial decomposition; fungal-dominated decomposition is associated with low nutrient fluxes. The EI was high for all treatments early in the study, but from May 2002 through 2004 the EI dropped in all treatments except the alfalfa treatments (Fig. 2a). Temporal changes in the CI were mirror-images of, and corroborated, the EI data (Fig. 2b). We conclude that the manure treatment had a relatively short-lived (i.e. one growing season) effect on the soil food web, whereas the benefits of alfalfa hay were more persistent. Diversity and the nematode Structure Index (SI) are general indicators of soil health. Diversity was reduced under alfalfa treatments as a result of the large abundance of 'enrichment opportunist' bacterivorous nematodes (Fig. 2c). The SI increased in all treatments as the complexity of the soil food web developed after fumigation. Recovery of the SI was not consistently influenced by organic mulch treatments. While faunal diversity and the nematode SI are considered to be indicative of general soil health, their exact relationships with soil fertility and the potential to support apple production are unclear at this time.

Fig. 2a. Nematode Enrichment Index

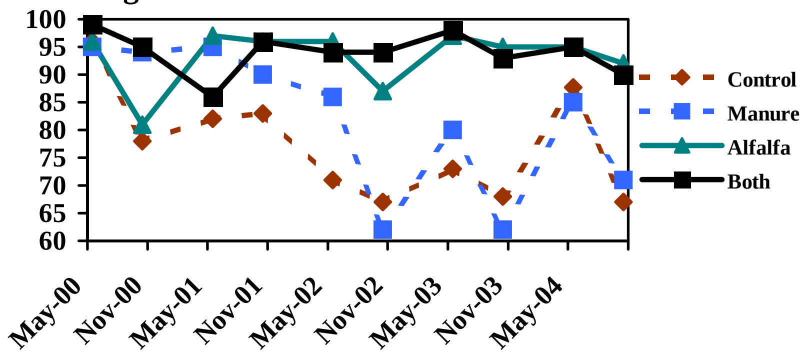


Fig. 2b. Nematode Channel Index

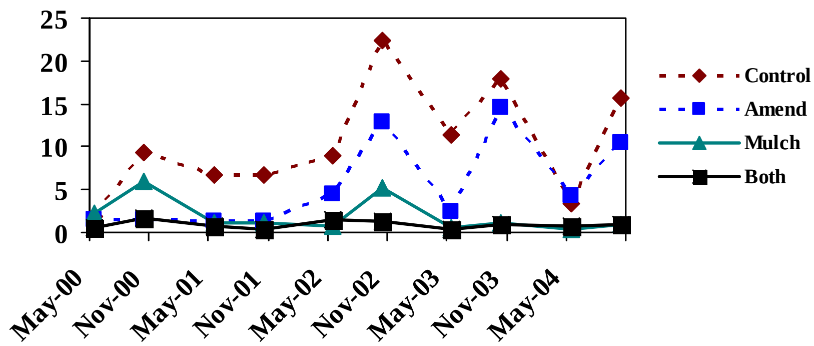


Fig. 2c. Simpson's diversity

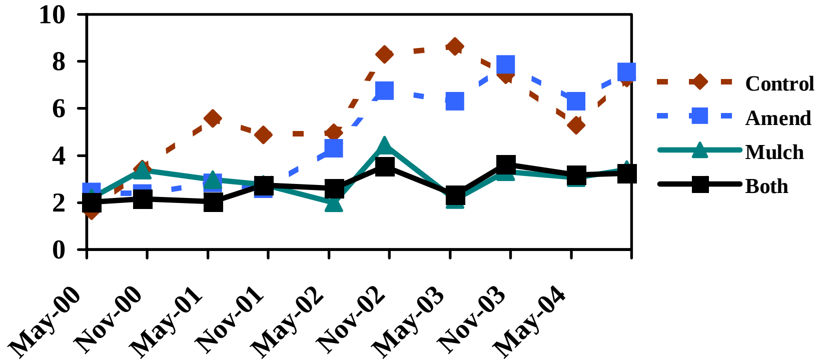
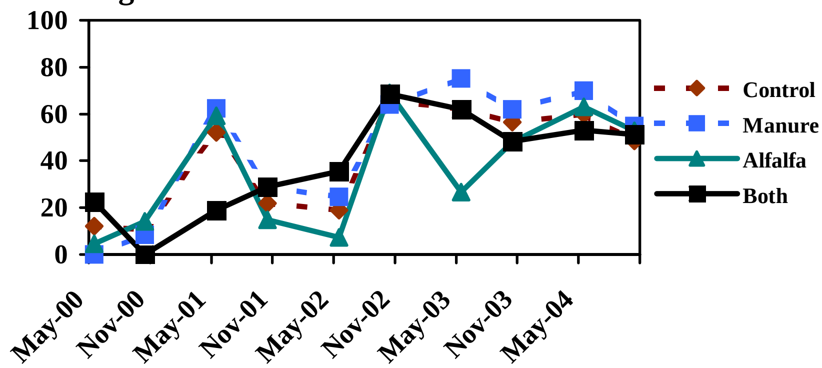


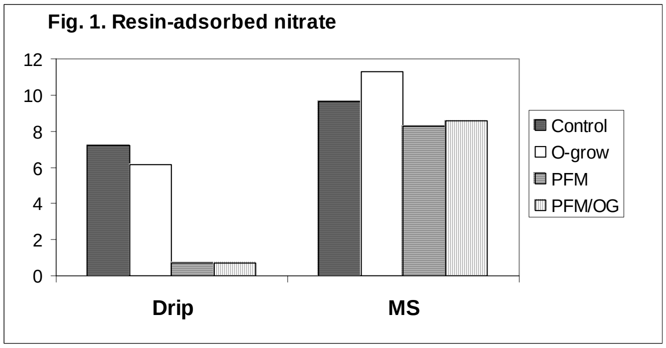
Fig. 2d. Nematode Structure Index



Spray-on paper fibre mulch/Ogogrow (Summerland):

Anion-exchange resin strips were used to measure the amount of nitrate and phosphate made available in 5-15 cm horizon soil in the field (*in-situ*) over two-week periods in April (before fertigation) and June (after fertigation started). Nitrate availability was reduced by the paper fiber mulch (PFM) (Fig. 1). This effect was more pronounced under drip than under microsprinkler irrigation, and the overall availability of nitrate was less under drip than under microspinkler irrigation (Fig. 1). Phosphate availability was also reduced by PFM and increased by Ogogrow compost (Fig. 2). Ogogrow contains significant quantities of P (Table 1) that are still being released into soil solution four years after initial application. Overall availability of P was comparable for drip and microsprinkler irrigation, but the effect of PFD on P availability was more pronounced under drip than microsprinkler (Fig. 2).

Because the PFM is a substantial source of C for microbial growth, it is likely that immobilization of N and P into microbial biomass contributed to the reduced availability of N and P under PFM. Unfortunately, attempts to directly measure microbial biomass P failed, due to interference with high background levels of available P in the compost-amended soil. Interestingly, the nematode indicators of enhanced microbial production/turnover and nutrient fluxes through the soil food web were generally increased under PFM (Table 2). Like nitrate and P, the effects of PFM on nematode indicators were generally less pronounced under microsprinkler than drip irrigation. It appears that fluxes of nutrients through the soil food web can increase without an increase in net nutrient mineralization (release). Increased fluxes of N and P through the soil food web were apparently not adequate to compensate for the high demand for N and P by the microbial biomass under PFM. The reductions in availability of nitrate and P under PFM and drip irrigation (nitrate only) could also have been due to leaching of nitrate and P from the top 15 cm of soil. Leaching of P was greater under PFM, particularly under drip irrigation (D. Neilsen, 2003 progress report).



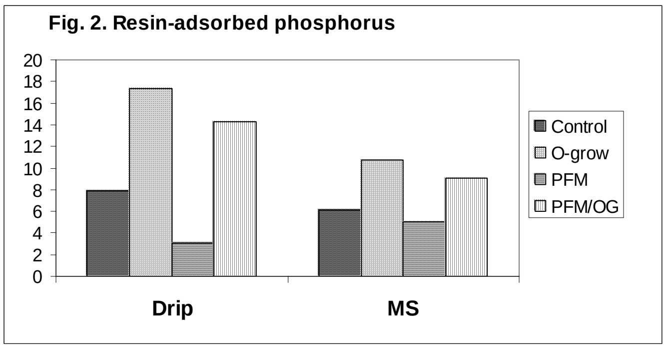


Table 2. Effects of mulch treatments and irrigation on populations of free-living nematodes that are indicators of enhanced microbial production and fluxes of N and P through the soil food web (BN, EO, EI), and soil food web structure/soil health (OP, SI). BN = bacterivorous nematodes; EO = enrichment opportunist nematodes; EI = Enrichment Index; FN = fungivorous nematodes; OP = omnivorous and predacious nematodes; SI = Structure Index; Diversity = Simpson's index of diversity.

	Total/100 g soil		**BN/100 g soil**		**EO/100 g soil**		**EI**	
	Drip	***MS***	***Drip***	***MS***	***Drip***	***MS***	***Drip***	***MS***
Control	1311	3106	817	1981	138	375	48	48
PF mulch	1870	3109	1196	1871	388	857	64	71
Ogogrow	1387	2445	761	1487	331	550	58	57
PF mulch/OG	3257	2719	1699	1480	1012	617	74	67
significance[1]	IxT,T,I		IxT,I		T		T	

	FN/100 g soil		**OP/100 g soil**		**SI**		**Diversity**	
	Drip	***MS***	***Drip***	***MS***	***Drip***	***MS***	***Drip***	***MS***
Control	233	469	46	259	47	50	6.7	7.4
PF mulch	403	907	133	233	47	54	8.6	8.6
Ogogrow	299	464	67	261	47	50	9.6	9.0
PF mulch/OG	1088	616	122	448	37	57	6.0	8.2
significance[1]	I		IxT,T		n.s.		T	

[1]Significance of effects in ANOVA. I = irrigation effect; T = mulch/amendment treatment effect; IxT = irrigation x mulch/amendment interaction effect.

Shredded paper/biosolids (Summerland):

Anion-exchange resin strips were used to measure the amount of nitrate and phosphate made available in the 5-15 cm horizon soil in the field (*in-situ*) during two-week periods in May 2003 and 2004, and in July of 2003. Anion-exchange resin strips were also used to perform single-point-in-time laboratory measurements of resin-available P in soil samples taken at the beginning of each incubation period. Shredded paper mulch (SPM) consistently decreased availability of P in root zone soil as in the PFM/Ogogrow experiment (Fig. 1). Overall, P availability was lower at 60 cm from the tree-row than at 30 cm from the tree-row (Fig. 1). Interestingly, biosolids had little net effect on P availability *in-situ* (Fig. 1), despite providing significant quantities of P (Table 1). In contrast to the *in-situ* measurements, the single-point-in-time measurements indicated an increase in available P in biosolids-treated soil. It appears that diffusional constraints, microbial immobilization, or root uptake may limit movement of biosolids-P to resin strips under field conditions.

The reduced availability of P under SPM is consistent with observations from the PFM/Ogogrow experiment. Reasons for the suppressive effect of SPM include leaching and microbial immobilization as discussed for the PFM/Ogogrow experiment.

Nematode indicators of enhanced nutrient cycling (bacterivorous and enrichment opportunist nematodes-Fig. 2, fungivorous nematodes-Fig. 3, Enrichment Index-Fig. 4) were increased by biosolids and SPM, with greatest abundances in the SPM/biosolids combination. It appears that the shredded paper could help to retain and then mineralize/cycle the N and P added in fertilizer and high-nutrient organic amendments. The nematode/food web Structure Index (SI), a measure of integrity of the soil food web, was suppressed by biosolids (Fig. 4). We are currently trying to determine if this effect is the result of heavy metals or other pollutants in biosolids, or a side-effect of high nutrient availability. While diversity and the nematode SI are considered to be indicative of general soil health, their relationships with soil fertility are unclear.

Fig. 1. Availability of P in-situ and in lab assay

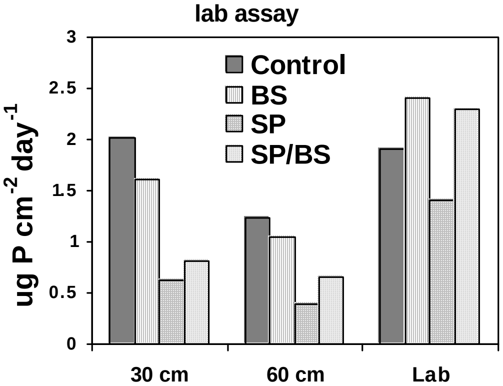


Fig. 2. Enrichment opportunist and other bacterivorous nematodes

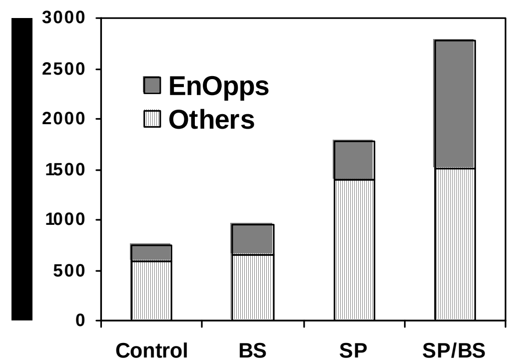


Fig. 3. Fungivorous and omnivorous/predacious nematodes

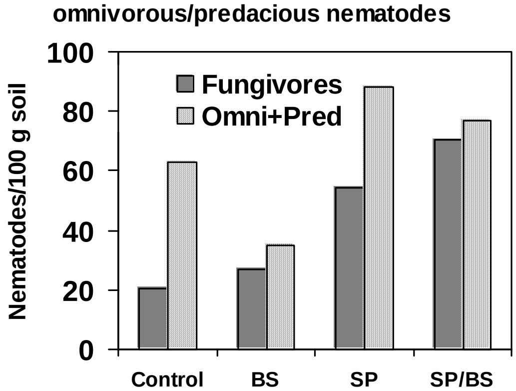
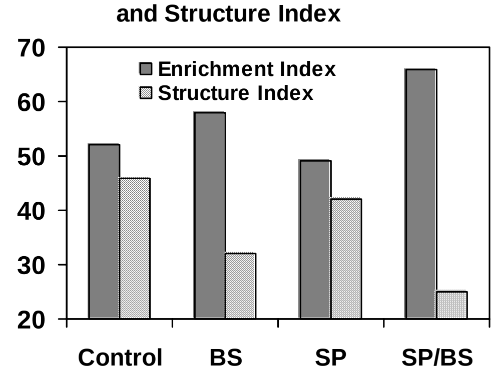


Fig. 4. Nematode Enrichment Index and Structure Index



Municipal yard waste compost experiment (Quincy): Municipal yard waste compost was applied in 2002. Both nematode indicators of enhanced nutrient cycling (Bacterivorous nematodes-BN, Enrichment Index-EI) were greater in soil under mulched than in non-mulched soil at Quincy.

Table 4. Selected indicators of phosphorus availability and nematode indicators of soil fertility at the Quincy experiment. Data are means of three sample dates from October 2002 through October 2003. '*' denotes values that is significantly greater (*P* < 0.05) than the corresponding value for mulched plots. Effect of mulch was significant at P < 0.01; Effect of mulch was significant at *P* = 0.02; BN-Bacterivorous nematodes, effect of mulch was significant at *P* < 0.001; EO-enrichment opportunists, effect of mulch was significant at *P* = 0.008; SI-Structure Index, irrigation treatment x mulch interaction effect was significant at *P* = 0.03.

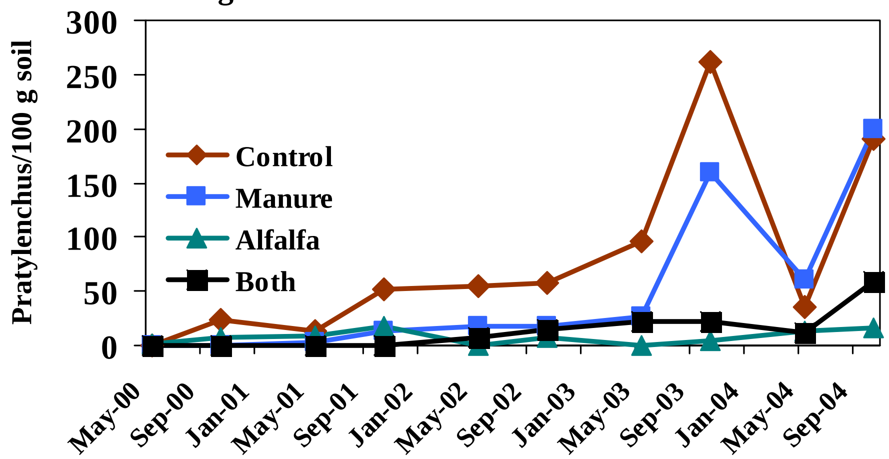
	Lab assay Resin-P (mg/kg)	***In-situ* Resin-P ($ug/cm^2/month$)** 30 cm	60 cm	*Average*	**BN (/100 g)**	**EO (/100g)**	**SI**
Non-mulched							
--Control	3.3	0.53	1.36	*0.95*	496	20	36
--Deficit	2.3	0.22	0.38	*0.31*	525	28	57
--Average	*2.8*	*0.38*	*0.87*	*0.63*	*511*	*24*	
Mulched							
--Control	17.7	2.08	3.04	*2.56*	1104	190	55
--Deficit	14.1	1.57	4.23	*2.90*	1085	107	46
--Average	*15.9**	*1.83**	*3.64**	*2.73**	*1094**	*149**	

Effect of mulch was significant at P < 0.01; Effect of mulch was significant at *P* = 0.02; BN-Bacterivorous nematodes, effect of mulch was significant at *P* < 0.001; EO-enrichment opportunists, effect of mulch was significant at *P* = 0.008; SI-Structure Index, irrigation treatment x mulch interaction effect was significant at *P* = 0.03.

Objective III: Root-lesion nematodes (RLN)

The Naches experiment was fumigated prior to establishment but populations of RLN have become re-established with time (Figure 1). From 2003 through 2004, RLN population densities in the control and manure plots were significantly greater (*P* < 0.01) than in the alfalfa and alfalfa/manure treatments (Fig. 1).

Fig. 1. Root-lesion nematodes - Naches



The SPM/Biosolids experiment was not fumigated prior to planting and treatment application. Population densities of RLN in soil increased under biosolids (Fig. 2, Exp. 2; $P < 0.01$) whereas SPM did not have a significant effect on RLN populations in soil. In a previous, similar experiment (Fig. 2, Exp. 1), SPM had a strong suppressive effect on RLN population densities in soil, and biosolids resulted in a minor but statistically significant increase in RLN population densities. RLN per g root were lower under SPM than under no mulch, regardless of biosolids (Fig. 2; $P = 0.02$). We have observed greater fine root biomass in the SPM treatments (Fig. 3), which may explain the lower RLN per g root in soil under SPM even though the SPM did not affect RLN population densities in soil.

Fig. 2. Root-lesion nematodes - Summerland

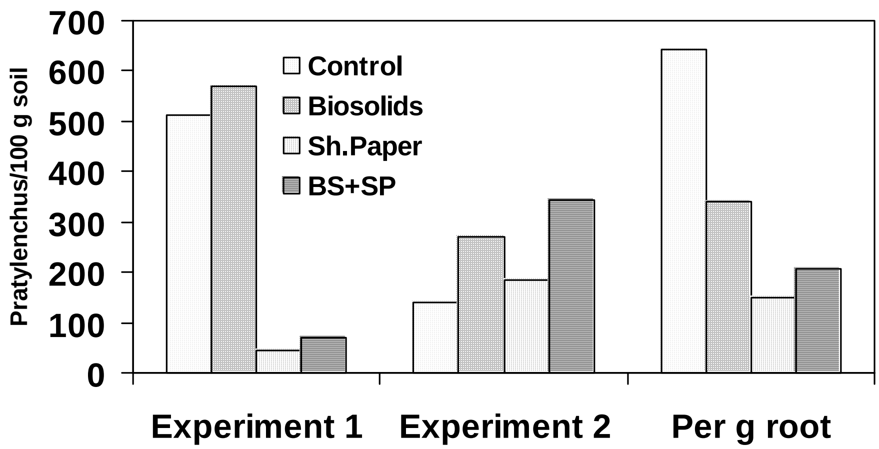
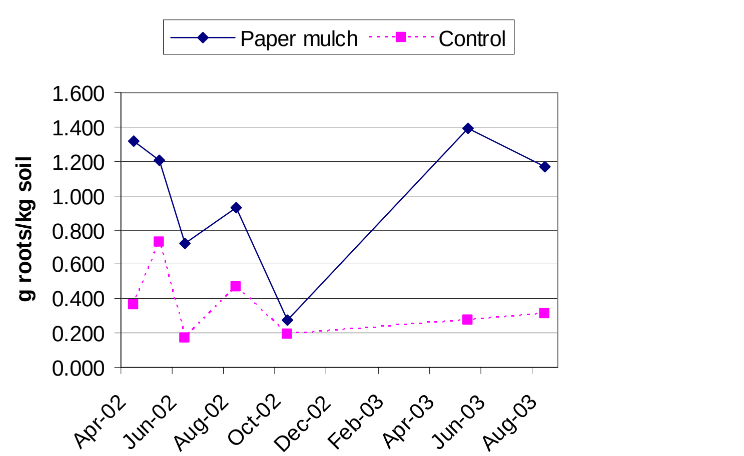


Fig. 3. Root biomass (to 30 cm) in mulched and non-mulched soil



The Quincy experiment was sampled three times between 2002 and 2003, and results were similar to the SPM/biosolids experiment at Summerland. The presence of mulch reduced the number of RLN per g root but did not affect population densities in soil (Table 1).

Table 1. Effects of mulch (municipal compost) and irrigation system on root-lesion nematode population densities at Quincy. '*' denotes value that is significantly greater ($P < 0.05$) than the corresponding value for mulched plots.

	***Pratylenchus* per 100 g soil**		***Pratylenchus* per g root**	
	Non-mulched	**Mulched**	**Non-mulched**	**mulched**
Control	1382	936	1129	380
Deficit irrig	1019	1143	696	446
Average	*1201*	*1040*	*913**	*413*
PRD irrig.	918		739	

In no case has an organic mulch effectively "controlled" a population of RLN, and we would not recommend the use of organic mulches specifically for RLN management. The moderate suppression of RLN we have observed under mulches does, however, add to the list of multiple benefits associated with mulches. The results from Naches suggest that organic mulches may be especially effective at reducing the rate of population buildup after fumigation. Future research should attempt to address the interaction between fumigation and organic mulches, and improve understanding of the mechanisms of nematode suppression.

BUDGET

Title: Influences of selected mulches and soil amendments on dynamics of nitrogen and phosphorus availability in the apple root zone
PI: Tom Forge
Duration: 2 yrs
Current year: 03-04
Project total: $34,000
Current year: $17,000
Project duration: 2 years

Year	**2003-04**	**2004-05**
Salary[1]	$15,300	$15,300
Equipment[2]	$500	$100
Supplies[3]	$400	$500
Travel	$800	$900
Total	$17,000	$17,000

[1]Summer student and short-term technical help: assistance with sampling, P extractions, nematode extractions, processing of decomposition samples.
[2] Ceramic cups, pvc caps, nylon mesh, and materials for assembly of mineralization tubes; coring tools.
[3] Expendable supplies: reagents for P extractions, hexanol, ion-exchange resins, plasticware, reagents & materials for ion-chromatography P analyses and LECO N analyses.