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Final Report
Improving Crop Yield and Soil Quality with Mulches, Organic Amendments and Cover Crops

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OBJECTIVES

1. Evaluate availability, cost and efficacy of locally available mulch materials.
2. Generate mulch materials in the orchards.
3. Develop spray-on mulch technology for multi-year weed control.
4. Evaluate effect of mulches on soil moisture - cooperative trials with D. Neilsen.
5. Evaluate long-term effects of mulches and cover crops in established trials.
6. Evaluate plant species for in-row living mulches.

SIGNIFICANT FINDINGS

1. Efficacy of wood wastes as a method of weed control in an established orchard (Wenatchee Valley College) was confirmed, while both wood chips (Summerland) and spoiled alfalfa hay (Naches) were found to provide effective weed control, soil moisture conservation and promote growth in newly planted orchards.

2. An orchard alfalfa hay cover crop provided greater biomass than grass under drip irrigation and provided 0.75 kg/m^2 dry matter per season, sufficient to maintain an established tree row mulch 1 to 1.5m wide.

3. Synthetic fibre (eg. landscape fabric) applied in the tree row at planting, and prior to application of spray-on mulch increased its efficacy and prolonged its weed controlling and other beneficial effects.

4. Detailed soil moisture measurements under different mulches, but particularly under spray-on mulch, confirmed that they provide an effective barrier to soil surface moisture loss.

5. Mulches, including spray-on mulch in grower trials, were more effective in promoting tree vigour in newly planted than in established orchards. The increased tree size advantage of mulched trees appears to be maintained as long as mulches are in place.

6. A number of plant species, including some low growing, low vigour species evaluated as orchard in-row cover crops (living mulches) showed potential for weed control but require orchard and cover crop management adjustments.

7. Favourable results with the use of the *Equisetum arvense* (field horsetail) for in-row weed control indicates potential for native allelopathic and non-allelopathic species as living mulches.

8. A preliminary cost/benefit analysis indicated a positive return from mulching by the 6th year of

production.

RESULTS AND DISCUSSION

1. Availability, efficacy and costs of mulch materials

a) Availability. Availability of mulch materials in both Washington and BC fruit growing areas was covered in two recent reports (Granatstein, Kirby and Van Wechel, 2003; Kuchta and Hogue, 2002). Availability in BC since then has increased due to implementation of "no burning" bylaws for land clearing wood in areas of the Okanagan and because of restriction on the use of hive burners by lumber companies to dispose of wood wastes. A few orchardists are using "chippers" for clearing their prunings and the wood chips for mulching.

b) Efficacy. As previously reported (Apple Horticulture/Pathology Research Review, 2004) weed control provided by wood waste mulches was excellent the year of planting. The only weeds present were at the edges where materials thinned out. The same pattern occurred in the second year. Weed control in mulched plots was excellent but herbicide was required to control the vegetation between the mowed space and the full depth mulch. In 2003 only trees in the hog fuel plots had (statistically significant) increased growth. In 2004 all mulched plot trees had increased growth (Table 1). This response pattern is very similar to those obtained in previous mulch trials in newly planted orchards.

Table 1. Relative efficiency of wood wastes and shredded paper mulch material in an Ambrosia/M.9 orchard planted in 2003.

Treatment[z]	Weed cover (%)		Leaf mineral (%)		TCSA (mm^2)	
	May 5/04	June 23/04	N	K	2003	2004
Check	18[y]	27	2.69 a	1.27 b	174 bc[x]	347 b
Shredded Paper	4	2	2.73 a	1.32 ab	199 ab	384 a
Hog Fuel	4	2	2.81 a	1.48 a	207 a	412 a
Chipped land clearing wood	3	1	2.72 a	1.40 ab	170 c	373 a

[z]Treatments applied at planting.
[y]Glyphosate at 1 kg/ha applied after each weed cover evaluation.
[x]Means within a column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

c) Costs. Although wood wastes are either free or of very low cost, since large quantities are required, the cost of transportation and application has prevented widespread use of mulches. Other mulch materials (hay, straw, bark, etc.) are either of limited availability or too costly at present for common use by the tree fruit industry.

2. Grow-your-own-mulch

Considering the present cost/benefits of mulch use with materials imported from outside the orchard, it becomes important to develop means of producing the necessary materials *in situ*. Two trials were

established in 2001, one in an established (4 yr. old) stone fruit orchard and another in a new high density apple orchard. Both orchards are drip irrigated, supplemented with sprinkler irrigation for frost, sunburn protection, etc.. In the first orchard, drought tolerant grass species were seeded but wild alfalfa invaded. In the second orchard pure stands of alfalfa, bromegrass and bromegrass-alfalfa were seeded in late 2001. In 2003, at the Summerland A site, four cuts of alley vegetation provided 0.78 kg/m^2 dry wt. of biomass, while in 2004, a year with similar precipitation, the same plots generated 0.75 kg/m^2 (Table 2). A previous trial (Wenatchee Valley College) found that 1.5 to 2.5 kg/m^2 dry mulch material are required to provide season-long weed control the year of establishment, depending on the composition of the biomass. Somewhat less than that amount was required to maintain the mulch's efficacy the following years. It appears, therefore, that the biomass produced at the Summerland A site would be sufficient to maintain a mulch but below the amount required to establish the mulch. The 2 cuts of any of the 3 treatments at Summerland B site would be below the adequate level to maintain the mulches.

Table 2. Yield of orchard alley produced mulch materials in two locations in Summerland in 2003 and 2004.

Site	Treatment	Yield (dry wt)			
		2003		2004	
		kg/ m^2	tons /A	kg/ m^2	tons/A
Summerland A	alfalfa/grass (70:30)	0.78[z]	3.47	0.75	3.4
Summerland B	grass	0.26[y]	0.97	0.38	1.7
	alfalfa	0.26	1.16	0.37	1.7
	alfalfa/grass (70:30)	0.24	1.07	0.29	1.3

[z]Yields at Summerland A from 4 cuts over the entire season.
[y]Yields at Summerland B from 1 cut on Sept. 13 in 2003 (establishment year) and 2 cuts in 2004, May 10 and July 4.

The data indicate that growing mulch material *in situ* is possible but further trials with sprinkler irrigated, fertilized alley swards of various species composition, alley widths, etc. in newly planted orchards are required.

3. Develop spray-on mulch technology for multi-year weed control

A trial to evaluate different underlays and materials applied to the row strip prior to applying the spray-on mulch was initiated in 2002 with the objective of extending its weed controlling period beyond a single season. In the first year of the trial all treatments provided excellent full season weed control. However, spray-on mulch applied over the polyethylene mulch treatments peeled off during the winter. The polyethylene mulch was replaced in 2003 by a very economical, non-woven polypropylene fabric mulch, fully permeable to water. Spray-on mulch was applied to this treatment and re-applied to all other spray-on mulch plots in June 2003 after controlling the few weed escapes, mainly near the trunks, where slits had been made in the underlays to accommodate the trees. Spray-on mulch was not re-applied in 2004.

Table 3. Effect of underlays and mulches applied prior to spray-on mulch (SOM) on weed control, growth and yield, in 2004, of Honeycrisp/M.9 planted in 2002.

Treatment	TCSA	Yield	Weed cover (%)		
	(mm^2)	(kg / tree)	May 3	June 25	Aug 13
Check	410 c[z]	4.6 b	33	44	19
Spray-on-mulch [y]	467 bc	6.8 ab	3	2	4
Compost / SOM	511 ab	8.7 a	2	4	2
Reemay cloth[x] / SOM	570 a	7.0 ab	2	2	2
Landscape Fabric (LF) / SOM	500 abc	5.8 ab	1	1	1
LF / Compost / SOM	524 ab	6.9 ab	1	3	2

[z]Means within a column followed by the same letter are not significantly different at the 5 % level according to Duncan's multiple range test.
[y] Slurry of recycled, pulped newsprint waste fiber plus chopped cereal stray.
[x] Thin extruded polypropylene row cover material.

Weed control was excellent in all treatments again in 2004 (Table 3) with only a few escapes near the tree trunks. The condition of the spray-on mulch in fall 2004 was excellent and effective weed control is anticipated for several more years, especially in treatments with underlays. A significant increase in tree vigour was recorded in 3 of the 5 spray-on mulch treatments. This is an increase over previous years and an indication that all mulched treatment trees will eventually be larger than the check trees. Only one treatment promoted significantly greater yield, but the trend in all treatment trees is to increased yields and, given less variability, will result in signficantly improved yields in coming years.

4. Evaluate effect of mulches on soil moisture - cooperative trials with D. Neilsen

Soil moisture measurements were taken at 0-15 cm depth in all mulched plots established through the years ('94, '97, '98, '99, 2001, 2002 and 2003). In all cases, summer soil moisture content was signficantly higher under mulches when measurements were taken just prior to the next irrigation period. Since soil moisture measurements were part of cooperative studies, the effect of mulches on levels and distribution has been reported on in detail by D. Neilsen.

5. Evaluate long-term effects of mulches in established trials

The objective in our mulch and organic amendment studies has been to examine the long term effects, ie. more than the 1-3 years of orchard establishment, to simulate growers' experience. Results of a 6 year trial on shredded paper, alfalfa hay and geotextile mulch and organic amendments in a Spartan/M9 study have been reported (Apple Horticulture/Pathology Research Review, Jan. 2001).

a) Shredded paper/organic amendment - 8 year study. In a Golden Delicious/M.9 trial initiated in 1997 all mulch treatments promoted increased growth (Table 4). This growth advantage has persisted (Table 4). Although the yields in this trial were greater in the mulched plots until 2001, this has not consistently occurred since then, and could be related to fruit thinning, alternate bearing of some trees in the plots and,

possibly, leveling off of bearing capacity for these trees.

Table 4. Effect of organic amendments and shredded paper mulch on growth and yield of Golden Delicious/M.9 planted in 1997.

Treatment	TCSA (mm^2)		Yield (kg / tree)	
	2001	2004	2001	2004
Check	669 b[z]	1126 b	8.6 c	10.7 a
Envirowaste [y] (Enviro)	672 b	1199 b	8.8 c	11.0 a
Enviro / Zn, Cu, B [x]	669 b	1133 b	9.3 bc	11.3 a
GVRD	709 b	1248 b	8.7 c	13.1 a
Enviro/Paper mulch [w] (PM)	1028 a	1584 a	11.0 a	13.4 a
Enviro / Zn, Cu, B/ PM	989 a	1531 a	11.5 a	12.8 a
GVRD [v] / PM	1021 a	1623 a	11.5 a	13.3 a
PM	931 a	1449 a	10.6 abc	11.5 a

[z] Means within a column followed by the same letter are not significantly different at the 5% level according to the Duncan,s multiple range test.
[y] Commercially composted biowaste, Aldergrove BC.
[x] Compost with added micronutrients.
[w] Shredded paper mulch replenished as required until 2002 and weeds, mainly in the non mulched plots, were controlled with glyphosate at 1 kg/ha as required.
[v] Minimally composted sewage sludge, Greater Vancouver Regional District, BC.

Mulched trees in a grower trial established in 2001 to evaluate spray-on mulch and organic amendments have also been larger than non-mulched trees from the beginning of the trial and continue to be larger (Table 5). Yields in the treatment plots, however, have not been greater. This may be related to the small fraction of the trees sampled (5 of 15), or factors mentioned above. A longer period of data collection is necessary for a more accurate assessment.

Table 5. Effects of spray-on mulch and surface applied compost treatments applied at planting and maintained since 2001, on weed control, growth, yield, and leaf N and K in Braeburn /M.9, Peachland, BC, 2004.

Treatment	Weed cover (%)		TCSA	Yield	Leaf (%)	
	May 4	July 28	(mm^2)	kg / tree	N	K
Check	11[z]	25	496 b[y]	6.3 a	2.80 a	1.45 ab
Spray-on Mulch (SOM)	2	10	636 a	6.9 a	2.67 ab	1.50 a
Compost + SOM	1	8	646 a	6.6 a	2.31 ab	1.51 a
Compost/ Zeolite + SOM	1	9	606 a	6.2 a	2.18 b	1.32 b

[z]Glyphosate at 1 kg/ha applied after each weed cover evaluation.
[y]Means within a column followed by the same letter are not significantly different at the 5 % level according to

Duncan's multiple range test.

c) Spray-on mulch / additives grower trial - 3 yr study. In another spray-on mulch trial started in 2001 weed control in treatment plots has been good but tree size is significantly greater in only 1 of 3 treatments (Table 6). Unlike the previous trial, this one was not initiated on newly planted trees. However, the lack of vigour response of the treatment with dichlobenil incorporated in the spray-on mulch may be related to the effect of the chemical rather than the effect associated with weed competition or moisture stress the year of planting before the mulch treatments were applied.

Table 6. Effect of spray-on-mulch treatments applied in 2001 and 2002 on weed control and tree growth of Granny Smith/M.9 planted in 2000, Kelowna B.C.

Treatment	Weed cover (%)			TCSA	N
	April 23[z]	July 23	July 22	(mm^2)	(%)
Check	5	55	4	1205 b[y]	1.45 ab
Spray-on-mulch (SOM)	3	18	0	1583 a	1.50 a
SOM / T[x]	2	17	2	1421 ab	1.51 a
SOM + dichlobenil	1	15	0	1201 b	1.33 b

[z] Glyphosate at 1 kg / ha was applied after each weed cover evaluation
[y] Means within a column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.
[x]T=tackifier (glue) added to the mulch at 2.5%.

d) Spray-on mulch grower trial - 3 yr study. In a third grower orchard spray-on mulch trial, with a simple comparison of mulched versus no mulch, there were no significant differences (Table 7). However, this orchard was well established when the trial was initiated. There are also indications that the mulched trees show increased vigour and may significantly exceed check plot trees in size if the trial was extended. Yields, like tree size, were not significantly different.

Table 7. Effect of spray-on mulch on weed control, growth, yield and leaf mineral content in Ambrosia/M.9 orchard planted in 1999, Summerland, B.C.

Treatment	Weed cover (%)			TCSA	Yield	Leaf mineral (%)		
	May 5[z]	June 23	Aug 6	(mm^2)	kg / tree	N	P	K
Check	5	18	30	385 a[y]	6.8 a	2.61	0.2	1.32
Mulch	3	4	13	419 a	7.1 a	2.64	0.2	1.32

[z]Glyphosate applied at 1 kg/ha each year after weed cover evaluation.
[y]Means within a column followed by the same letter are not significantly different at the 5 % level according to Duncan's multiple range test.

6. Evaluating plant species for in-row living mulches

a) Low growing ornamental species. Five species of dwarf ground cover plants were obtained from a nursery in spring 2003. Thirty 2 x 2 cm plugs were planted 10-15 cm apart in plots 1.2 by 0.9 m at the Summerland Research Centre. The plots were microsprinkler irrigated briefly each day during the warm period and foliar 20-20-20 applied weekly during establishment. Two species established quickly, 2

moderately fast while one was slow in establishing (Table 8). After the establishment period, plots were not weeded and by the following season showed differences in capacity to out-compete weeds (Table 8). The 3 most competitive species, *Arabis alpina, Saponaria ocymoides* and *Thymus serphyllum* had only a few weak weeds in the plots. *Saponaria* was the most vigorous and provided the best cover. It is however, difficult to propagate vegetatively. *Thymus* and *Arabis* have medium vigour, somewhat less competitive to weeds and both relatively easy to repropagate. In addition, *Arabis* may spread from seed. The potential of the 3 best species, however, over this short evaluation period, appear less than fully satisfactory for in-row living mulch purposes. A larger screening program which included native species would be necessary to discover the best living mulch candidates.

Table 8. Evaluation of low growing ornamental species as potential orchard in-row ground covers, 2003-4.

Ground cover spp.	Soil cover (%) 90 d post planting	Weeds/m^2 1 yr. post planting	Potential[z](1-5) Post 2nd season
Arabis alpina	83	5	2
Cerastium alpinum	70	15	0
Saponaria ocymoides	100	4	3
Sedum spathulifolium	15	9	0
Thymus serphyllum	100	4	2

[z]includes 1)in place performance, 2nd year, 2) ease of repropagation from original stand, 3) performance in coarse soil under normal microsprinkler irrigation scheduling.

b) Wenatchee Valley College living mulch trial. A trial was established in an 8-yr old Gala/M.26 orchard in mid-May, 2004. Six perennial landscape species were planted (alyssum, wild strawberry, wild ginger, sweet woodruff, creeping thyme, and scotch moss). Twenty entries of annual and perennial legumes, and colonial bentgrass, were planted (white clover, strawberry clover, kura clover, subclover, medics, trefoil) singly and in combination. Handweeding was carried out from May through July. Crop establishment and weed competitiveness were noted through the season, and select biomass samples were taken. A late August planting of selected legumes was also done to determine best timing to avoid weed problems. Weed pressure, mainly annual grasses, was very high. Only the white clovers and the bentgrass performed well without extensive handweeding. Strawberry clover also established a cover, but more slowly. In weeded plots, alyssum almost reached 100% cover by fall. The fall planting had much less weed pressure and several species (trefoil, kura clover, medic) had excellent germination and growth with no weeding, compared to poor emergence in the spring planting.

c) Naturalized in-row cover crop in Wenatchee Valley College orchard block. The alleys of a Cameo/M26 orchard planted in 1996, trained on a V-trellis, were seeded with a trefoil-clover mix and Companion grass. The legume cover crops died off in the alleys but became established in the tree rows and out-competed the weedy species previously there. Herbicide applications were stopped in these rows in 2001 and a healthy legume stand persisted into 2004.

d) *Equisetum arvense* as a living mulch. A trial was initiated in an established grower orchard (Braeburn/M.9 and Gala/M.9) in Summerland with established stands of *Equisetum arvense* (field horsetail) in 2003. Plots with *E. arvense* and plots without were either kept free of weeds with glyphosate application or allowed to grow weeds until late summer. The same plots were treated in a similar way in 2004. The herbicided plots (+) were treated with 1 kg/ha glyphosate in early May and on June 23. Plots with no herbicide and without horsetail had weeds cut with a mechanized hand weeder (Weed Eater).

Table 9. Effect of *Equisetum arvense* as a living mulch (in-row cover crop) on weed control and tree nutrition in an established Braeburn/M.9 and Gala/M.9 orchard, 2004.

Treatment		May 4/04 (% Cover)		July 28/04 (% Cover)		N	K
E. arvense	Herbicide[z]	Weeds	*E. arvense*	Weeds	*E. arvense*	(%)	(%)
-[y]	_	2	0	0	0	1.90 ab[x]	1.98 a
-	-	36	0	40	0	1.87 ab	1.94 a
_	_	1	73	0	38	2.10 a	1.93 a
_	-	5	73	3	83	1.92 ab	1.79 a

[z]Glyphosate applied at 1 kg/ha on May 2 and June 23.
[y]Weeds cut on June 23.
[x]Means within the column followed by the same letter are not significantly different at the 5% level according to Duncan's multiple range test.

In spring, plots without horsetail left untreated with herbicide had a medium stand of annual weeds that were cut in June and counted in the July cover evaluation (Table 9). Plots with the horsetail remained almost weed free for the entire season, whether treated with glyphosate or left untreated (Table 9). Treatment with glyphosate devigourated the horsetail but did not result in horsetail mortality. Throughout the growing season there was no indication that horsetail was affecting the vigour of the trees or colour of foliage. There were no significant differences on levels of any of the leaf minerals, including N.

Cost benefit of long term use of mulches. A preliminary cost/benefit analysis of mulch use in a Spartan/M.9 trial planted in 1994 (Apple Horticulture/Pathology Research Review, 2002) indicated that the use of mulches for weed control in the establishment years is clearly more expensive than the use of herbicides. However, by the 6th year of production, because of the greater vigour of mulched trees and the resulting increased yields, the use of mulches showed a positive cost/benefit. A detailed analysis will be published.

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