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Does Organic Matter, Matter?

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The benefits of increasing the application of organic matter to orchard soils include the potential to: 1) directly add multiple plant nutrients to the soil; 2) improve soil structure by creating soil aggregates, thereby improving soil aeration; 3) improve soil nutrient and water retention capacity thus buffering the soil against adverse conditions; and 4) intensify biological and biochemical activity in the soil.

Nutrients

Organic matter contains a wide range of plant nutrients and other constituents. For example, a vegetation/poultry manure/straw compost produced and used at Agriculture Canada's Agassiz Research Centre contained (by dry weight) 39.3% carbon, 2.5% nitrogen, 2.3% phosphorus, 2.7% potassium, 6.1% calcium, 0.9% magnesium, 417 ppm (parts per million) zinc and 7 ppm copper. Therefore unlike chemical fertilizers, addition of organic materials involves co-application of multiple essential plant nutrients. However, in contrast to chemical fertilizers, nutrient content of organics are low. Thus if the compost cited above were to be used to apply 50 pounds of nitrogen (N) per acre and the compost contained a typical moisture content averaging 50% and were to mineralize 30% of its total N, about 12 tons of compost per acre would be required to supply the desired 50 pounds. There are important variations in mineral composition of organic amendments as summarized in Table 1. The amount of N that can be mineralized within a year of incorporation shows considerable variation with low carbon: nitrogen ratios being generally associated with higher N supplying powers.

Soil Structure

It is desirable to create a porous soil structure to allow ready penetration of roots, oxygen and water through the soil profile. Organic matter can bind soil grains together to create large aggregates resistant to breakdown. One measure of soil aggregation is particulate soil carbon, which is measured after 16 hours of shaking the soil in water with glass beads. Particles larger than 53 microns are considered resistant to mechanical breakdown. Particulate carbon values have been found to double beneath bark mulches while particulate C values are often very low within the herbicide strips of conventional orchards indicating degraded soil structure.

Nutrient and Water Retention Capacity

Organic matter has a large capacity to retain nutrients and water as indicated by moisture contents which can exceed 100% by weight and cation exchange capacities, which can be 10 times greater per unit weight than most coarse-textured soils. These characteristics act to improve plant access to water and nutrients although making noticeable improvements in cation exchange capacity (CEC) of a loamy sand, for example, requires volumetric additions ranging from 10-20% by volume. Thus over the surface foot of a loamy sand soil, this would require mixing in a 1.2 to 2.4 inch depth of organic matter.

Biological Activity

A major effect of increasing soil organic matter is to increase the magnitude and diversity of soil organisms, stimulating beneficial biochemical reactions. Many examples of this have been cited in other presentations in this session and so will not be discussed in more detail here.

Orchard Soil Organic Matter Content

There is a wide range of soil organic matter contents occurring naturally in Pacific Northwest orchards. For example, in a recent survey of 228 orchards and vineyards in the Okanagan Valley in British Columbia, organic matter concentration averaged 3.4% but ranged from 0.35% to 11.5% (Fig. 1). It was not possible to directly link organic matter levels to orchard performance but soils with <2% organic matter frequently occurred in warmer (southern) locations on coarse-textured soils. These orchards are most likely to benefit from augmenting organic matter contents.

Methods of Using Organic Matter in Orchards

Organic amendments can be applied in orchards in different ways. Applications can be mixed into the surface layers as an amendment or applied to the soil surface as a mulch. Either application can be made to the whole orchard floor or localized to some fraction of the orchard where problems are judged to be more severe.

Field Trials

Over the past 20 years at the Pacific Agri-Food Research Centre (PARC) in Summerland, BC, a series of randomized, replicated experiments often of multi-year duration have been undertaken in high density apple orchards on dwarfing rootstocks. The trials were designed to test the effectiveness of various organic matter treatments to improve orchard performance when applied as incorporated amendments or surface mulches. Many of these field experiments have been summarized and published elsewhere. Those interested in further details can consult the literature cited.

<u>Amendment Experiment</u>

One of the earliest experiments undertaken at PARC Summerland involved a 1998 planting of Braeburn apple on M.26 rootstock. Ninety tons/acre of a composted biosolids (Ogogrow trade name) was worked into a sandy soil to a one-foot depth in the planting row. The material, which had a relatively high phosphorus content (approx 1.5 to 2.0%), significantly improved total tree shoot growth which was associated with improved tree P nutrition (Table 2). Addition of various clay minerals with a high water retention capacity (vermiculite, zeolite and bentonite) did not further augment growth.

<u>Combined Amendment and Mulching Experiments</u>

a) Naches, WA.

An experiment comparing mulching and soil amendments was carried out for the first 5 years of a ‘Braeburn’ orchard on M.9 planted at a 4 x 8.5 foot spacing on a site with severe replant disorder in Naches Washington. The surface mulch treatment was comprised of alfalfa applied at 45 tons/acre and maintained at a 4-inch depth by annual additions. The amendment treatment involved a one-time application of minimally composted dairy solids applied just after planting. Additional experimental details can be found in Forge et al. (2013). Mulching most affected orchard performance resulting in increased tree size, greater cumulative yield and larger fruit size in three of the first four fruiting years. In one of these years the larger fruit had decreased fruit firmness. In contrast the one time soil amendment had minor effects on growth and yield.

b) PARC, Summerland, BC.
A long-term mulching and amendment trial was also carried out at the federal research station in British Columbia, Canada. The orchard was a planting of ‘Spartan’ apple on M.9 rootstock spaced at 4 x 11.5 feet. Seven mulching/amendment treatments and their combinations were applied in 1994 with 5 replicated 4 tree plots. The soil was a coarse-textured, gravelly, sandy loam, which received daily drip irrigation and N fertigation applying 70 to 100 pounds N/acre annually. Additional details on methods and results have been summarized in several publications (Neilsen et al., 2003a, b). Selected plant and soil responses are summarized in Table 3 and demonstrate superior performance of mulched trees as indicated by larger trunk cross-sectional area (TCSA) and higher yield for trees grown with paper mulch. Tree performance of treatments receiving surface applications of a biosolids amendment was similar to trees grown in check treatments in a weed-free tree row maintained by regular applications of herbicides (Roundup). The biosolids amendment was effective at increasing soil P and soil organic carbon and nitrogen. It was noteworthy that soil infiltration capacity was lowest in the geotextile (black fabric) treatment where organic matter additions were totally excluded from the soil surface.

<u>Spray-on mulch</u>
A series of experiments were undertaken in four grower orchards to compare the performance of apples on M.9 rootstock when grown in a treatment involving planting time application of a spray-on mulch comprised of waste paper and straw. Additional details of the mulch, method of application and experimental sites and measurement variables can be obtained from Cline et al. (2011). All experiments were maintained for a minimum of five growing seasons and were located on sandy loam soils, which were judged as likely to have improved moisture regimes when they were mulched. Improved tree growth and yield were observed for mulched trees relative to control trees grown in herbicide strips in three of the four test orchards. An exception was an ‘Ambrosia’ orchard where the spray-on mulch treatment was compared late in a previously established planting between the fourth and eighth growing season. In this orchard, tree performance was similar between control and mulch treatments.

A spray-on mulch experiment was also undertaken at the Pacific Agri-Food Research Centre at Summerland, BC on ‘Gala’ on M.9 rootstock for six growing seasons commencing at planting. Additional details can be found in Hogue et al. (2010).

Although trees grown with spray-on mulch were larger, their cumulative yield was similar to control trees grown within herbicide strips. It was subsequently found that soil at this site had deficient potassium levels. It is therefore apparent that mulch treatments can be ineffective, if, as in this study they do not correct a major growth limitation. There was insufficient potassium released from this high calcium mulch to overcome low leaf potassium concentrations, which averaged 1.1% at this site.

Organic Soil Management

An experimental, organically certified block on a silt loam soil was managed for the first six growing seasons to compare the effectiveness of four organically acceptable orchard floor management systems. All treatments received compost applications in the first year to the planting hole and as an in-row surface application, the latter sufficient to provide 50 pounds per treated acre of nitrogen. Subsequently, from the second (2007) to sixth (2011) growing seasons, four different in-row orchard floor management systems were maintained, including 1) compost/annual tillage; 2) an alfalfa mulch grown in-situ, mown and applied to the in-row area; 3) a bark mulch over which annual mown hay was applied; and 4) a permanently installed black fabric mulch (Neilsen et al., 2013). Soil samples collected every second year have documented consistent improvements in soil nutrient content and biological activity. For example, the soil in the surface four inches immediately below any applied mulches have shown large increases in soil carbon (and organic matter) concentration, especially as a result of application of alfalfa and bark mulches (Fig. 2). This has resulted in increased organic matter status for these soils relative to nearby conventional or un-irrigated, native sites on the same soil. There have been few differences in growth and yield of the 'Ambrosia' apples on B.9 rootstock grown in the experiment, implying that all treatments are acceptable for organic production systems on this soil and growers could adopt the system most cost-effective for their situation.

Concluding Remarks on Organic Matter in Orchards

Over the past 20 years a wide range of field experiments have been conducted in grower and government research station orchards to test the effectiveness of increased application of organic matter applied either as surface mulches or amendments incorporated within the soil profile. The experiments have been conducted in high-density apple orchards on dwarfing rootstocks and involved randomized and replicated comparison of treatments carried out for 3-5 years. The number of sites where improved orchard performance (primarily increased tree yield) has resulted from strategies to increase use of organic matter in orchards is summarized in Table 4. From this data it can be concluded that use of surface mulches has generally been more effective than incorporation of amendments and that benefits have not always been observed.

In the course of experimentation it was discovered that organic amendments could be ineffective on sites with fertile soils or with strong fertigation programs. High frequency irrigation (four times daily with small volumes of water; Neilsen et al., 2010) could be more effective than surface mulching while over-irrigation resulting in excessive leaching of nitrogen mineralized from compost could be detrimental. Organic application could be ineffective when an important limitation such as replant disease or a nutrient deficiency such as potassium was unaffected by the treatment. In one orchard it was found that surface mulching and amendment incorporation buffered against water stress and associated reductions in fruit size, which occurred from accidental failure in the irrigation system.

Literature Cited

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Table 1. Variation in C:N ratios and potentially available Nitrogen (PAN) in first year for composted and non-composted organic amendments

			Estimated PAN*	
Organic amendment	N (%)	C:N	Mean	Range
Broiler litter	3.84	9.5	42	27-54
Dairy solids compost	1.99	19.8	6	-2 to 16
Broiler litter compost	4.05	8.8	38	28-40
Pelleted fish	9.4	4.5	77	nm
Yard waste	2.0	13.3	19	12-28

Adapted from Gale et al. (2006).

* PAN was estimated from field studies of N uptake by corn after soil incorporation of amendments. Ranges given for materials tested at two locations (Washington, Oregon) over two years.

Table 2. Effects of various incorporated (surface foot) soil amendments on first year growth of 'Braeburn' apple on M.9 rootstock.

Treatment	Total shoot growth (ft)	Leaf P (% dw)
Check	23.3c[z]	0.24c
Ogogrow (O)	30.2a	0.32ab
Vermiculite (V)	23.6c	0.23c
O+Zeolite	27.9ab	0.34a
O+Bentonite	25.6bc	0.30b
O+V	29.2a	0.30b

[z] Means within columns significantly different at $p \leq 0.05$ if followed by different letter.

Table 3. Plant and soil responses to selected mulching and amendment treatments maintained from 1994-2001 in a 'Spartan' on M.9 rootstock apple orchard.

	TCSA (cm^2)		Yield (lbs/tree)		Soil properties[y]			
	1997	2001	1997	2001	Total C	Total N	Soil P	Infiltration
Treatment[z]					(%)	(%)	(ppm)	(gal/hr)
Check	4.6c	11.5d	7.0c	32.3b	1.0c	0.10bc	40b	1.4b
Biosolids amendment	4.5c	11.6d	9.9bc	32.3b	1.9a	0.18a	205a	3.7ab
Paper mulch	7.4a	17.4a	14.3a	44.9a	1.3bc	0.12b	26b	2.6b
Geotextile	58bc	12.4d	11.5ab	35.2b	0.9c	0.09c	29b	0.9c

[z] Check (herbicide strip), 45 tons/acre composted biosolids in 1994 and 1997, shredded office paper maintained annually, black geotextile fabric permeable to irrigation water.

[y] Soil properties measured in surface foot in 2001.

[x] Means within columns significantly different at $p \leq 0.05$ if followed by different letter.

Table 4. Summary of number of orchards exhibiting improved performance in multi-year experiments conducted over the past 20 years by PARC-Summerland in grower and research high density apple orchards on dwarfing rootstocks.

Experiment type	Number of sites	Sites with improved performance[z]	Success Ratio
Surface mulch	12	8	0.667
Incorporated amendment	16	5	0.313

[z] Increased yield and frequently larger tree size.

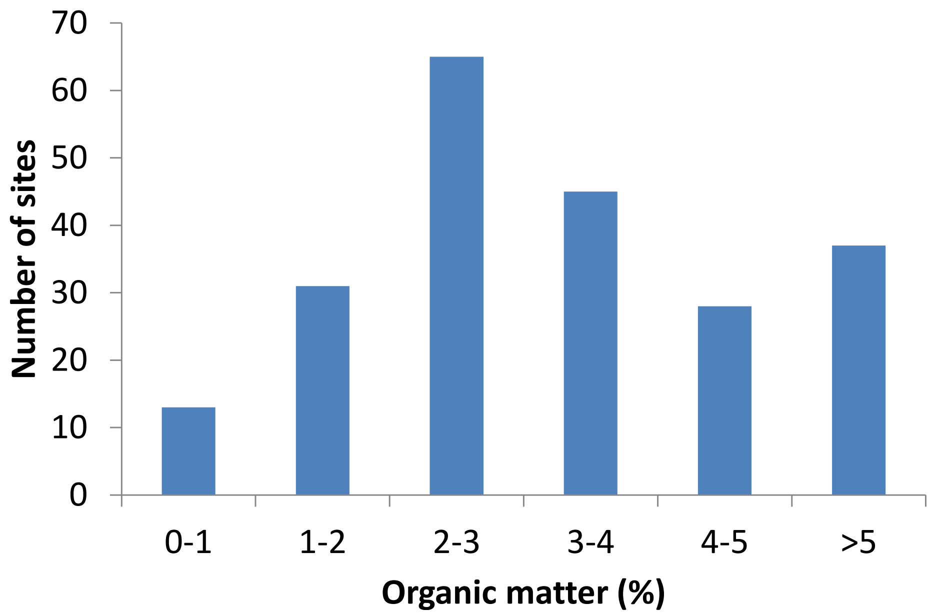

Figure 2. Number of orchard and vineyard soil samples with a range of organic matter content (2007 survey, Okanagan Valley, BC. 288 sites).

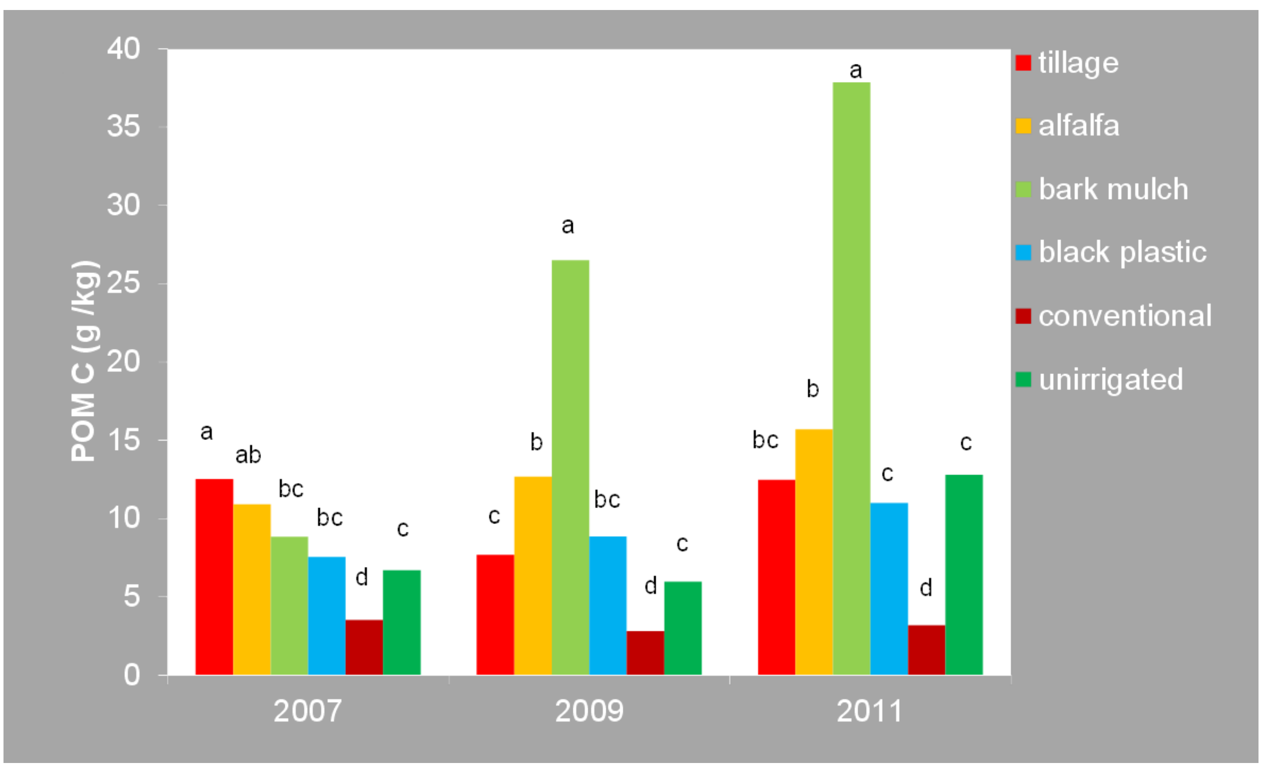

Figure 1. Particulate carbon (C) concentration in surface 0-10cm of soil affected by various treatments 2, 4 and 6 years after experiment initiation.