Effect of Soil Compaction on Strawberry Root Health and Yield

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Most strawberries in the northeastern United States are grown as perennials on flat beds. In sections of fields where compaction has occurred and water accumulates on the surface after rain, strawberry plants usually perform poorly. Most soil compaction in commercial agriculture is attributed to the use of heavy equipment, especially when soils are wet (Hakansson et al. 1988). Highly compacted soils have low porosity that impedes root growth, reduces aeration, and diminishes water holding capacity and permeability. Low permeability and aeration also favor infection of plant roots by soil pathogens (Moots et al. 1988; Juzwik et al. 1999). Wing et al. (1995) found a negative correlation between soil compaction and strawberry root health in a survey of 54 strawberry fields. However, it is unknown to what extent poor performance is due to standing water favoring pathogen infection versus the direct effect of increased bulk density on plant health and feeder roots. Furthermore, the extent of compaction in New York strawberry fields is unknown, as well as how compaction in individual fields changes over time.

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The objective of our study was to address several questions related to the effect of soil compaction on strawberry root health and yield without standing water or other confounding biological factors. We set out to: 1) determine the range of compaction that exists in typical commercial perennial strawberry fields, 2) determine if compaction changes with the age of the planting, 3) determine if soil pathogens influence the response to compaction, and 4) quantify the direct effects of compaction on strawberry plants in a production field.

Materials and Methods

Experiment 1. During summer of 2006, a penetrometer was used to measure in-row soil compaction at 6 depths (3-in intervals) at 10 locations in each of 17 strawberry farms throughout New York State representing a range of soil types. Measurements were taken when soil was moist and had a chance to drain after rainfall or irrigation.

Experiment 2. In July 2003, soil penetrometer readings were taken in each of seven ¼-acre fields aged 1 to 7 years at a single commercial farm with a Conesus silt loam soil in Trumansburg, NY. Four locations were arbitrarily selected in each ¼-acre field and readings were taken both within and between rows at 7 depths (3-in intervals). The farm did not employ tractors once plants were established, so the only significant source of compaction would have been foot traffic from pick-your-own customers and a walk-behind rototiller. The relationship between field age and compaction was determined.

Experiment 3. In 2005, surface soil was collected from three farms across New York State and transported to Ithaca. Each of the farms had a history of problems with strawberry root health and black root rot. Soil was divided into two lots, and half was fumigated with methyl bromide for two weeks under a plastic tarp. Soil from each lot was placed in 12-liter plastic pots and five levels of bulk density were established with five replicates of each. Vermiculite was used to decrease density, and mallets were used to increase density to desired levels. Bulk density ranged from 0.6–1.2 g/cm3 averaged over the entire pot, depending on soil source and amount of compaction imposed. Bulk density levels of 1–5 were equally spaced within the range. We were not able to measure compaction of soil in pots with a penetrometer. Strawberry plants cv. Jewel were planted into the pots and then were grown outdoors in a trench for more than one year. In July 2006, after exposure to winter, soil was washed off the roots and root health was assessed according to the method of Wing et al. (1995). Feeder root health score was regressed against relative bulk density to determine if a relationship existed.

Experiment 4. In May 2004, three levels of soil compaction were established on a virgin site containing a fine sandy loam Arkport soil with excellent drainage. Two levels of compaction were achieved by using a commercial road compactor (10 or 3 passes), and a third level was not compacted artificially. Each level was replicated 4 times, with treatments randomly assigned to plots. After compaction, strawberry plants cv. Jewel were planted into 4-row plots with 4 ft between rows. Whole plots were then subdivided into three subplots, with each subplot 13 ft in length. Subplots were subjected to three levels of between-row compaction. Levels were achieved using a heavy tractor, a light tractor, or using no tractor to accomplish standard tasks (cultivation, mulching, and pesticide applications, approximately 5 passes per year) (Pritts and Handley 1998). Several times during the following three years, soil compaction was measured in the row middles using a penetrometer. Yield was obtained from two 6-ft sections per plot in 2005 and 2006, and plant density was obtained after runner establishment at the end of 2004. The relationship between compaction and plant performance was determined by analysis of variance.

Results

Experiment 1 and 2. In commercial farms, compaction increased with increasing depth (Figure 1). Strawberry rooting depth is approximately 30 cm, but few strawberry sites (<1%)

exhibited extreme compaction (> 2.0 MPa, 300 psi) at that depth, and 19% exhibited moderate compaction (>1.3 MPa, 200 psi). The majority of sites had compaction of less than 1.0 MPa at a 30 cm depth (Figure 2). Furthermore, there was no relationship between the age of a planting and soil compaction on a farm where heavy equipment had not been used.

Experiment 3. Plants growing in fumigated soils typically had healthier feeder roots than plants in unfumigated soils (Figures. 3–5), although those in unfumigated soils did not exhibit characteristic black root rot symptoms. Only plants in fumigated soils responded negatively to compaction, and then only in two of the three sites.

Experiment 4. Differences in levels of imposed soil compaction were maintained throughout the experiment. Both preplant treatments (whole plot means) and postplant treatments (subplot means) resulted in predictable patterns of compaction that increased with soil depth (Table 1). At the highest levels of compaction in the rooting zone, bulk densities ranged from 1.35 to1.65 g.cm-3 depending on soil source.

Increasing compaction from preplant treatments resulted in lower plant densities (2004) and yield (2005 and 2006), but did not affect individual fruit weight in 2005. Individual fruit weight was greater in 2006 in the uncompacted preplant treatment. The yield reduction from the heavier preplant compaction treatment was approximately 10% (Table 2).

Between-row compaction from postplant treatments did not affect plant density (2004), yield (2005 and 2006) or individual fruit weight (2005) (Table 3). Fruit weight was slightly smaller in 2006 under the most between-row compacted treatment.

Even under compaction imposed by a road compactor and heavy tractor, yields were high in this particular site.

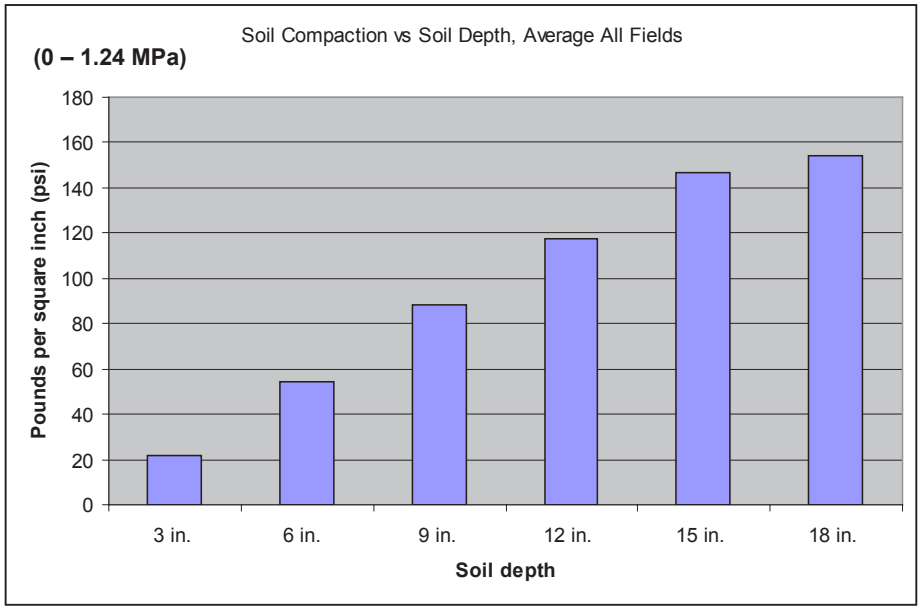


Figure 1. Soil compaction as affected by soil depth averaged across 10 sites in each of 17 farms in New York State.

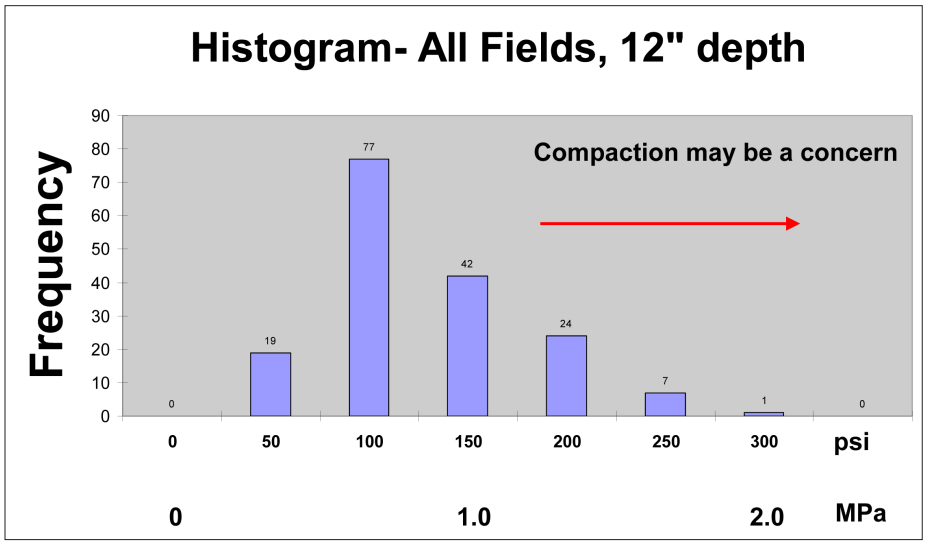


Figure 2. Soil compaction at a 12 inch depth across 10 sites in each of 17 farms in New York State.

Table 1. Preplant (in-row) and postplant (between-row) treatment effects on soil compaction (MPa) at 6 depths after 3 years.

	Soil depth (cm)					
Treatments	**8**	**16**	**24**	**32**	**40**	**48**
Preplant						
Minimum	1.09	1.61	1.70	1.77	1.85	2.22
Moderate	1.37	1.74	1.74	1.81	1.95	2.15
Maximum	1.45	1.88	2.03	2.08	2.19	2.37
Pooled standard error = 0.19						
Postplant						
Minimum	0.72	1.07	1.23	1.45	1.72	1.99
Moderate	1.05	1.46	1.55	1.61	1.82	2.06
Maximum	1.63	1.91	1.94	2.12	2.33	2.55
Pooled standard error = 0.06						

Discussion

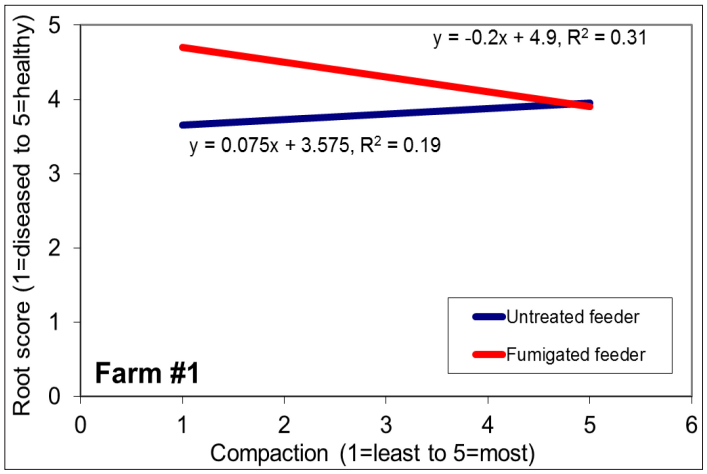
Our survey of typical strawberry fields did not reveal compaction levels in the range where problems have been observed with other crops, perhaps because perennial strawberries are not intensely cultivated nor are fields planted annually. We were able to study the long-term impact of heavy foot traffic during harvest on soil compaction, but found no relationship with field age. Apparently, strawberry fields can recover from compaction from foot traffic that occurs during harvest, at least in a typical loamy soil. In perennial plantings, straw mulch and strawberry plant residue are incorporated after harvest and this likely decreases compaction and contributes to recovery. In a study examining the effect of preplant cover crops on strawberry root health, Seigies et al. (2006) found that a continuous planting of perennial strawberries left the soil less compacted than growing other vegetable and field crops where standard bed preparation and cultivation practices were used. Compaction is probably not a limiting factor in most

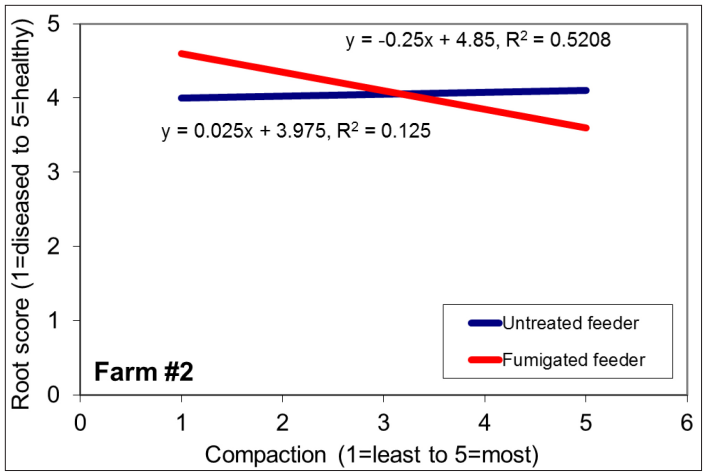
Table 2. Effects of preplant compaction in 2004 on plant density, yield and individual fruit weight over the following three years. Multiply yield by 1840 to obtain lbs/acre.

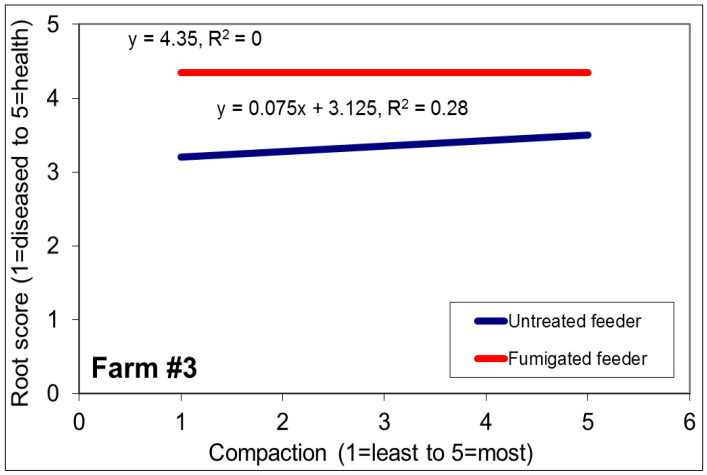
Treatment	Density (no./m)	Yield (2005) (kg/4 m)	Yield (2006) (kg/4m)	Indiv. fruit wt. 2005 (g)	Indiv. fruit wt. 2006 (g)
Minimum	44.0	7.83	22.0	12.0	13.9
Moderate	31.0	7.73	21.2	12.2	12.4
Maximum	28.6	7.19	20.3	12.1	12.7
***P* value**	**<0.05**	**<0.05**	**<0.05**	**NS**	**<0.05**

Table 3. Effects of postplant compaction in 2004 on plant density, yield and individual fruit weight over the following three years. Multiply yield by 1840 to obtain lbs/acre.

Treatment	Density (no./m)	Yield (2005) (kg/4 m)	Yield (2006) (kg/4m)	Indiv. fruit wt. 2005 (g)	Indiv. Indiv. fruit wt. 2006 (g)
Minimum	35.7	7.47	20.7	12.1	13.6
Moderate	31.0	7.90	21.3	12.0	13.0
Maximum	36.7	7.38	21.7	12.2	12.6
***P* value**	**NS**	**NS**	**NS**	**NS**	**<0.05**







Figures 3–5. Interaction between fumigation and soil compaction on feeder root health in pathogen-infested soils from farms in eastern (Figure 3, left), central (Figure 4, center) and western (Figure 5, right) New York State.

commercial perennial production fields, provided drainage is adequate.

Plants in fumigated soils usually had healthier feeder roots than plants grown in unfumigated soils. With fumigated soils, high bulk density/compaction decreased root health, as expected. However, compaction did not have an effect on root health in unfumigated soils. This result was unexpected. It is possible that we needed to achieve higher levels of compaction/bulk density to be able to detect an effect, as we were not able to achieve extreme levels of bulk density in plastic pots. It is also possible that pathogens did not thrive in pots, providing little potential interaction with a change in soil physical properties.

In the field study, preplant compaction negatively affected plant density, and yields were subsequently reduced approximately 10%.

Figure 6. Applying soil compaction treatments to a virgin site in Ithaca, NY.

Figure 7. Result of soil compaction treatments on a sandy loam soil.

Figure 8. Result of heavy between-row compaction with a tractor.

Figure 9. Strawberries grown in a matted row within the field experiment.

Postplant treatments had measurable effects on soil compaction between rows, but had no effect on strawberry yield. Individual fruit weight was slightly affected by between-row compaction in 2006, but this was the only variable affected.

Although we were not able to examine the entire range of soil types on which strawberries are grown, we conclude that strawberries are remarkably tolerant of compaction when soil has adequate internal drainage and when pathogens are not present. In our study, heavy compaction before planting had only a small effect on strawberry plant performance (10%), and subsequent cultural practices that confined compaction to the aisle had little to no impact. Heavy foot traffic, even in perennial strawberry plantings on flat beds, did not permanently affect soil compaction. Although plants tended to have healthier feeder roots in fumigated soils, we did not find an interaction between compaction and the presence of soil pathogens. The shallow root system of strawberries, coupled with annual straw mulch incorporation and confinement of equipment to row middles, may allow strawberries to avoid problems with compaction that are commonly observed with other crops.

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Marvin Pritts is a research and extension professor who leads Cornell's berry crop management program. **Mary Jo Kelly** (deceased) was a research technician who worked for Dr. Pritts. **Cathy Heidenreich** (deceased) was an extension specialist who worked with Dr. Pritts.

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