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Furrow Erosion from Manure and Whey Amended Topsoil and Subsoil

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Summary:

Applying manure to recently exposed subsoil increases crop productivity and soil organic carbon. We monitored furrow irrigation runoff from 18-m long plots to determine if manure application decreased soil erosion by increasing soil organic matter. Greater organic carbon did not decrease erosion. Soil erosion from topsoil treated with cottege cheese whey was greater than erosion from any subsoil treatment. Soil chemical factors seemed to have a greater effect on erosion than organic carbon. Phosphorus in irrigation runoff was related to erosion and soil phosphorus concentration.

Keywords:

Furrow Irrigation, Soil erosion, Organic Carbon, Phosphorus.

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Furrow Erosion from Manure and Whey Amended Topsoil and Subsoil

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Introduction

Soil erosion can impact water quality off-site and crop productivity on-site. On furrow irrigated fields with uniform slope, much of the topsoil eroded from the upper end of the field deposits on the lower end (Trout, 1996). Crop yields on eroded upper ends can be 25% lower than the rest of the field (Carter et al., 1985).

A long-term study was established in southern Idaho in 1991 to determine if eroded soil productivity could be improved with crop rotation and fertilizer amendments (Robbins et al., 1997). They found that applying manure to exposed subsoil restored dry bean production to that of conventionally fertilized topsoil. Manure application also increased organic matter. Based on a literature review, Hudson (1994) concluded that as organic matter increased from 3 to 5% available water capacity doubled, which should influence soil erosion and infiltration. Applying liquid swine manure to soil boxes decreased runoff and total dissolved solids concentrations during laboratory simulated rainfall (Mitchell and Gunther, 1976). Using a field rainfall simulator, Gilley and Eghball (1998) found that a single manure or compost application had no significant effect on runoff and soil erosion. No published information is available about the effects of manure application on soil erosion in irrigation furrows.

The field site used by Robbins et al. (1997) has topsoil and subsoil plots with a range of soil organic carbon and phosphorus concentrations. The main goal of our study was to relate soil phosphorus concentrations with runoff phosphorus concentrations. A secondary goal, which we report in this paper, was to compare sediment and phosphorus in runoff from these plots. We hypothesized that increased organic carbon from manure applications would reduce soil loss during furrow irrigation.

Materials and Methods

The study was conducted in southern Idaho on Portneuf silt loam (coarse-silty, mixed, superactive, mesic Durinodic Xeric Haplocalcids) with approximately 1% slope. Plots were established in 1991 for a long-term study to determine if eroded soil productivity could be improved with crop rotation and fertilizer amendments (Robbins et al., 1997). In April 1991, the top 0.3 m of soil was removed from long strips down the slope of the furrow irrigated field to create topsoil and subsoil strips. Four fertilizer treatments were established in 21-m wide strips across the field, perpendicular to subsoil and topsoil strips. The original treatments were conventional fertilizer, manure and two rates of cottage cheese whey. The conventional treatment was fertilized according to soil test for calcareous soils. Fresh dairy manure was applied in April 1991 at 44 Mg ha^{-1} (air-dry weight) and in October 1991 at 93 Mg ha^{-1}. Manure was only applied to the subsoil plots. The cottage cheese whey was a byproduct produced by adding 3 kg H_3PO_4 to each 1000 kg of milk. Whey was surface applied in April 1991 through gated pipe at 230 m^3 ha^{-1} (low whey) and 920 m^3 ha^{-1} (high whey). In November 1994, the low whey treatment was converted to a manure treatment by applying 74 Mg ha^{-1} (air-dried weight) dairy manure to subsoil and topsoil low whey plots. Whey was reapplied to the high whey plots in November 1994 at 500 m^3 ha^{-1}.

One, 30-cm deep soil sample was collected from each plot in May 1998. Samples were analyzed for calcium, magnesium, potassium, sodium, phosphorus, pH, electrical conductivity, calcium carbonate equivalent and organic carbon. Soil samples for phosphorus analysis were also collected from the furrow soil surface prior to each irrigation.

Soil and phosphorus loss were measured after dry beans were harvested in September 1998 and after small grain was planted in May 1999. One-wheel compacted furrow was monitored on two topsoil and two subsoil strips during both irrigation tests, giving two replications for each treatment. Irrigation water was supplied by gated pipe at the upper end of each fertility treatment to avoid interactions of water flowing from one treatment on to another. The 1991 manure treatment was irrigated the first day, 1994 manure treatment the second, and conventional and high whey treatments on the third day in 1998. Weather conditions were similar all three days with no precipitation occurring. In 1999, the 1991 and 1994 manure treatments were irrigated the first day and the conventional and high whey treatments were irrigated the second day. Weather conditions were similar again between the two days.

Runoff was measured with small trapezoidal long-throated flumes installed 18 m down slope from the gated pipe. Inflow rate was set at 28 Lpm and was measured periodically with a gallon bucket and stopwatch. This was a high inflow flow rate for 18 m long furrows, but was chosen to simulate erosion from the upper end of an irrigated field. Each irrigation test lasted slightly more than 4 h. Sediment samples were collected with small troughs pressed against the flumes and poured into 1-L Imhoff cones. Sediment volumes in the cones were read after 30 min of settling (Sojka et al., 1992). Sediment samples from 24 Imhoff cones were collected to correlate settled sediment volume with sediment concentration (sediment concentration [mg/L] = 0.88 * sediment volume [mL]). Flow rate and sediment concentration were measured 5, 15, 45, 75, 135 and 255 min after runoff began (5, 10, 30, 30, 60, 120 min intervals).

Two, 50-mL water samples were collected for phosphorus analysis each time a sediment sample was collected. One sample was filtered (0.45 micron) in the field immediately after collection and stabilized with boric acid. This sample was analyzed for ortho-phosphorus. The unfiltered sample was analyzed for total-phosphorous.

Following the September 1998 irrigation, we collected samples from the surface 2 cm of soil on the beds between furrows for aggregate stability analysis. Samples were analyzed according to a procedure described by Kemper and Rosenau (1986) as modified by Lehrsch et al. (1991).

Flow rate was integrated over time to calculate cumulative runoff for a furrow during an irrigation. Sediment, ortho-phosphorus and total-phosphorus concentrations were multiplied by flow volume for each time interval to calculate the mass of soil, ortho-phosphorus and total phosphorus lost with runoff. Flow-weighted concentrations for an irrigation were calculated by dividing cumulative mass by cumulative volume. Since we only monitored a portion of two blocks, we did not use analysis of variance. Instead, statistical comparisons were conducted using paired t-tests between treatments with $P<0.05$ using four reps (2 irrigations x 2 plots).

Results

Increasing organic carbon through manure application did not decrease soil erosion in this study. In fact, some of the greatest amounts of soil loss came from plots with the greatest organic carbon concentrations (fig. 1). Cumulative soil loss was similar for conventionally fertilized subsoil plots with 0.45 % organic carbon and manure treated topsoil or subsoil plots with 0.9 to 1.1 % organic carbon. Soil loss from the topsoil high-whey plots was almost twice that of any fertility treatment on the subsoil plots (fig 2) even though the high-whey plots had similar or greater organic carbon than the subsoil plots (table 1). The greater soil loss from the high-whey topsoil was not caused by greater runoff because there were no measurable differences in cumulative runoff among treatments.

Conventional thinking is that erosion increases as aggregate stability decreases. However, the subsoil plots tended to have lower aggregate stability than the topsoil plots (fig 3). Soil loss differences probably resulted from soil chemical differences among fertilizer treatments on topsoil and subsoil. The calcium carbonate equivalent was between 230 and 260 g kg^{-1} for subsoil plots and 4 to 11 g kg^{-1} for topsoil plots. Additional carbonate may have helped cement soil particles together, reducing soil detachment during irrigation. Phosphoric acid in the cottage cheese whey may have reduced the cementing by carbonates on the high-whey topsoil plots but the additional carbonates in the subsoil plots could have buffered the effects of added phophoric acid.

Linear correlations between soil loss and soil calcium, magnesium, and potassium concentrations were not significant. Soil loss did correlate with soil sodium concentration but the coefficient of determination was only 0.21. Since we analyzed the upper 30-cm of soil as a composite sample, soil chemical differences near the soil surface were not detected. It is possible that chemical differences in the surface layer may have contributed to soil loss differences among treatments. We need to conduct a more rigorous investigation of interacting parameters to explain erosion differences.

Total-phosphorus concentration in runoff was related to sediment concentration (fig. 4), but no statistical differences in cumulative total-phosphorus loss were measured among treatments. Cumulative ortho-phosphorus loss, however, was greatest from plots that received manure applications in 1991 and 1994 (fig. 5). Average flow-weighted ortho-phosphorus concentrations in runoff from manure treated plots were more than two times greater than the concentrations from high-whey and conventional treatments. Greater phosphorus concentrations probably resulted from greater amounts of phosphorus in the soil (table 2). The high-whey subsoil treatment was an exception. Soil phosphorus concentrations were similar for high-whey subsoil and 1994 manure topsoil (table 2), but 1994 manure topsoil had much greater cumulative ortho-phosphorus loss (fig. 4). There apparently was an interaction among soil erosion, soil phosphorus concentration and phosphorus loss in runoff.

Conclusions

Applying manure to exposed subsoil increases crop productivity and soil organic carbon. However, increasing soil organic carbon did not decrease erosion during these furrow irrigation tests. Soil chemical factors apparently had greater effect on erosion than soil physical factors. Soil loss from whey treated topsoil was greater than from any fertility treatment on subsoil. More rigorous data analysis, and possibly more replications, may show interactions among soil chemistry and erosion.

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Table 1. Soil Organic Carbon in Surface 30 cm.

Treatment	Percent Organic Carbon Subsoil	Percent Organic Carbon Topsoil
Conventional	0.44	0.81
1991 Manure*	0.96	0.86
1994 Manure#	1.02	1.05
High Whey	0.58	0.84

* Manure was only applied to subsoil in 1991.

\# Cottege cheese whey was applied to subsoil in 1991.

Table 2. Average Soil Test Phosphorus Concentrations for Surface Soil Collected from Furrows Prior to Each Irrigation.

Treatment	Soil Test Phosphorus Concentration (ppm) Subsoil	Soil Test Phosphorus Concentration (ppm) Topsoil
Conventional	33	20
1991 Manure*	76	14
1994 Manure#	120	58
High Whey	55	36

* Manure was only applied to subsoil in 1991.

\# Cottege cheese whey was applied to subsoil in 1991.

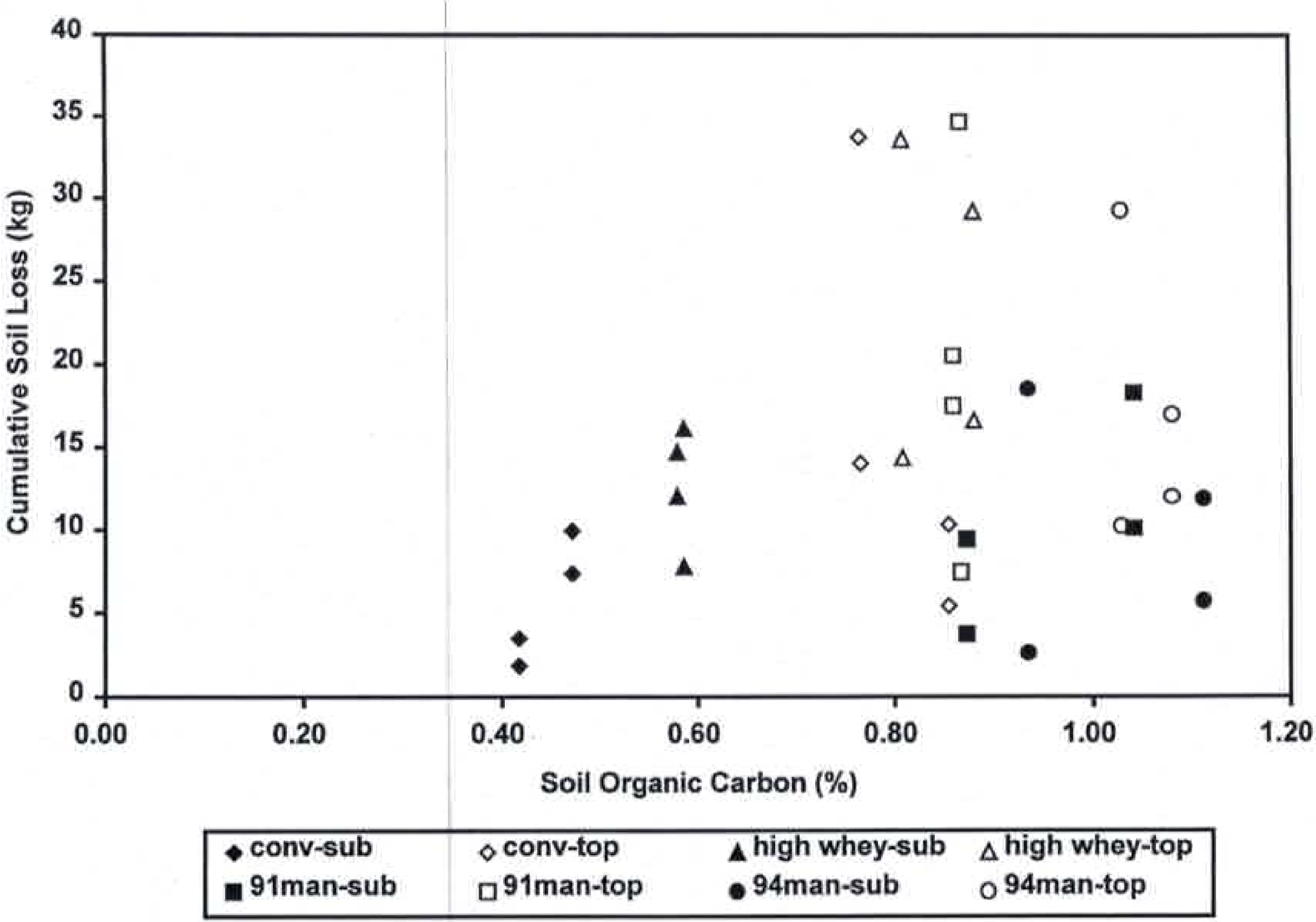

Figure 1. Soil organic carbon versus cumulative soil loss for each furrow irrigation test.

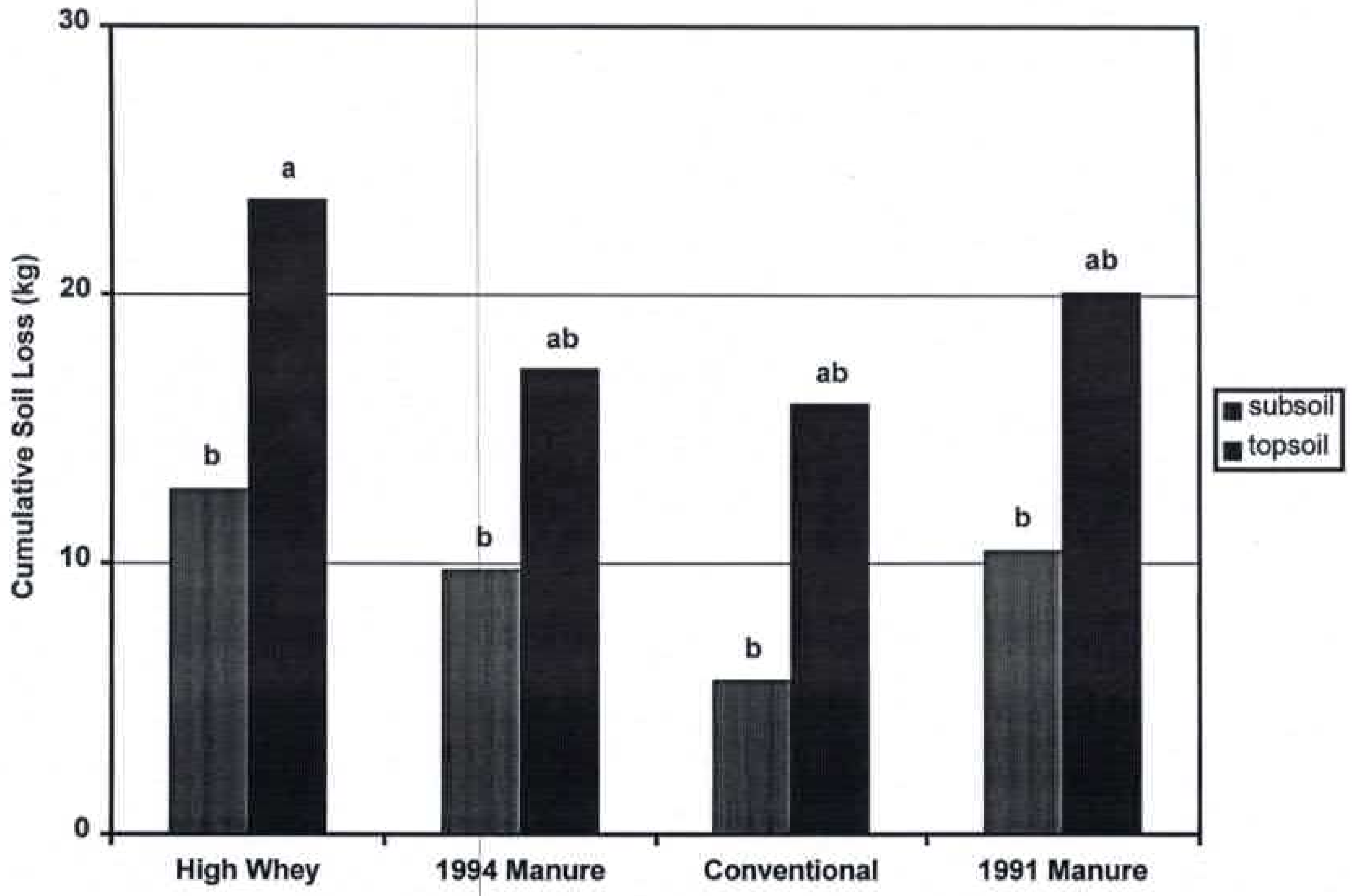

Figure 2. Average cumulative soil loss per irrigation for each fertility treatment. Treatments with different letters are significantly different ($P<0.05$).

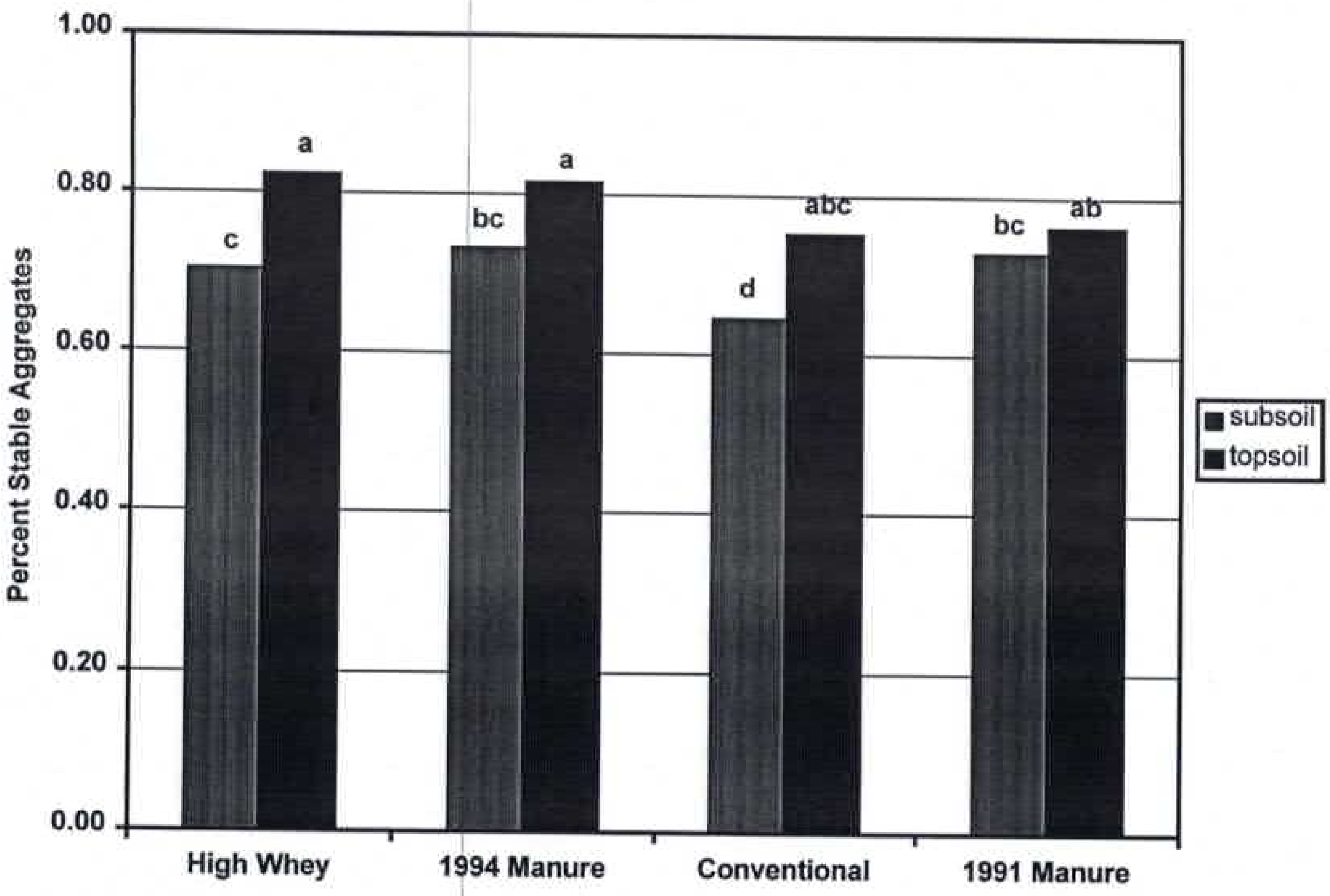

Figure 3. Percent stable aggregates for surface soil from each fertility treatment. Treatments with different letters are significantly different ($P<0.05$).

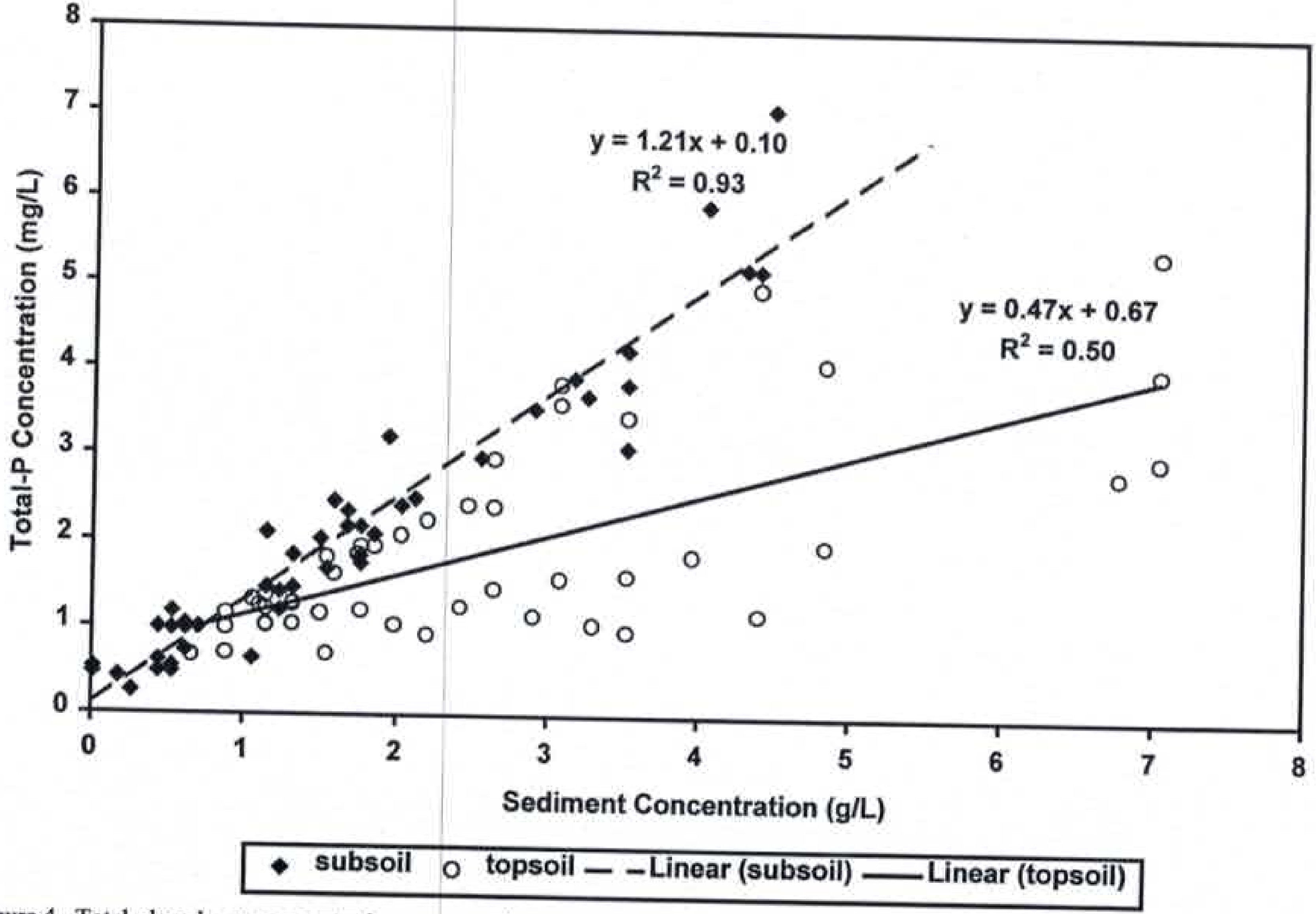

Figure 4. Total-phosphorus concentration versus sediment concentration for furrow irrigation runoff.

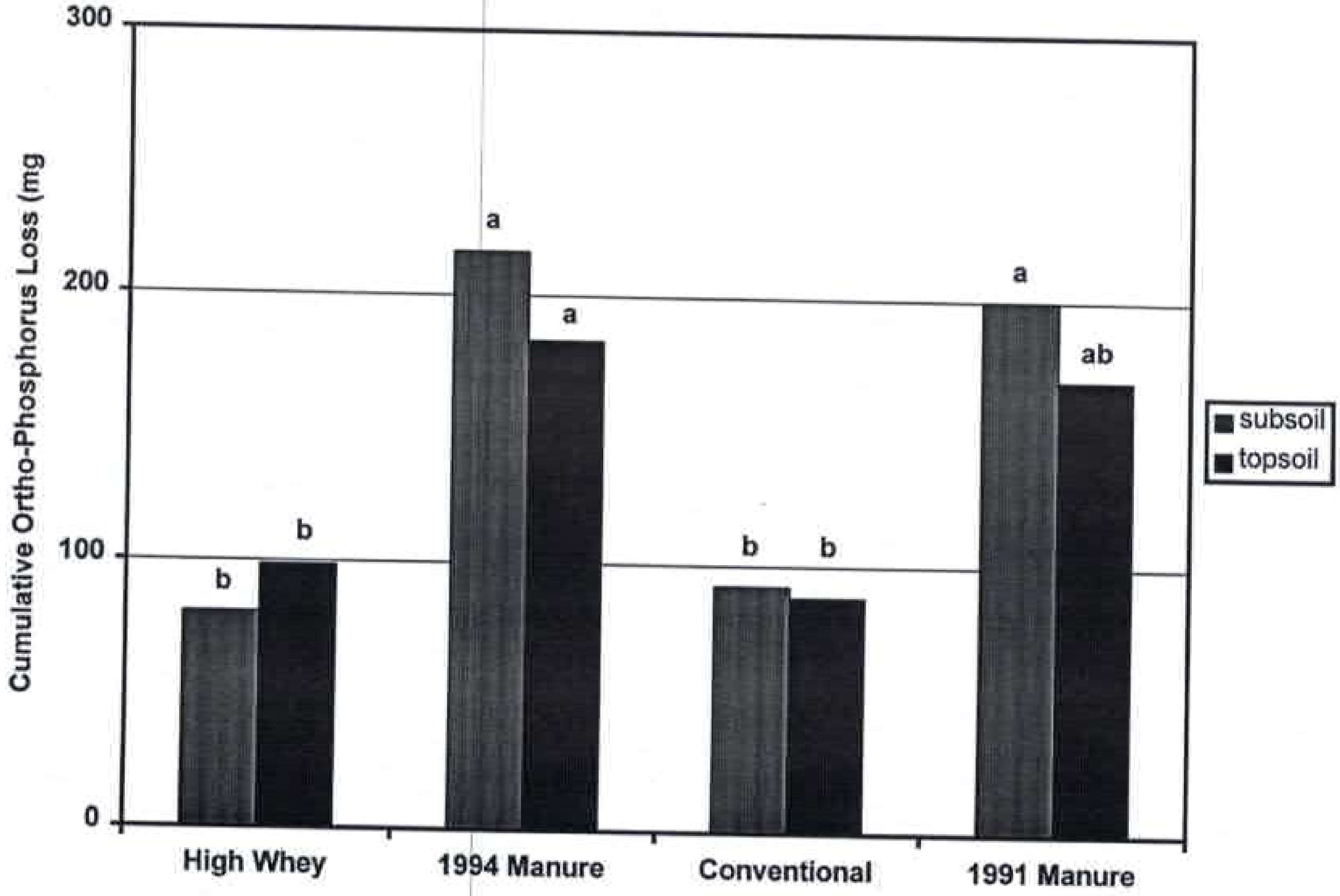

Figure 5. Average cumulative ortho-phosphorus loss per irrigation for each fertility treatment. Treatments with different letters are significantly different ($P<0.05$).