Short communication

Evaluation of compost and straw mulching on soil-loss characteristics in erosion plots of potatoes in Prince Edward Island, Canada

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Abstract

The intensive use of Prince Edward Island (PEI) farmland for potato (Solanum tuberosum L.) production draws concern because of soil physical degradation under the intense tillage and other heavy traffic associated with the mechanisation of this crop, and the resulting vulnerability of sloping fields to hydraulic erosion. Growing public consciousness and pressure in favour of sustainable agriculture have engendered farmer interest in a possible place for commercial farm by-products in commercial cropping. Using existing natural erosion plots in PEI, the effects of compost amendment and straw mulching were assessed in terms of soil loss and soil physical condition on a fine sandy loam (Orthic Podzol). The treatment materials are local by-products of potato farming systems, and were used for an insight into the likelihood of sustainable commercial use. Compost had no effect on soil loss. Mulching reduced soil loss by almost 50%. Both treatments increased soil water content by 6–7%. Among the treatment effects on soil physical characteristics, soil penetration resistance below the root zone was reduced almost 20%; and, in the third year of the study, soil aggregate stability increased 7% with compost. Shear strength showed a strong \( p<0.05 \) regression relationship \( (R^2=0.835) \) with bulk density. © 2000 Elsevier Science B.V. All rights reserved.

Keywords: Soil erosion; Erosion plots; Compost amendment; Mulching; Soil structure

1. Introduction

With recent emphasis on sustainable agriculture and its tie-in with biological recycling (Mäder et al., 1996; Siegrist et al., 1998), attention is increasingly turning to agronomic practices, such as straw application and compost use for the improvement of soil physical conditions, particularly under such intensive row-crop systems as exist on the fragile sandy loams of Prince Edward Island (PEI), Canada, (MacDougall et al., 1988). Expectations of soil physical improvement under these and similar circumstances include increased soil moisture, improved soil structure and a concomitant increase in soil resistance to erosion (Reganold et al., 1987), general soil organic matter enrichment (Beyer et al., 1999) and a general enhancement of important soil physical characteristics (Russell, 1973).
Organic-matter amendments have been heavily relied upon in some cultures and become central to sustainable farming systems. Sustainable agriculture has moved, as a recognised farming system, from Europe and North America to Asia, South America and Africa. It is estimated (Geier, 1999) that the annual rate of increase in organic farming enterprises is 20–30%, and contributes substantially to a global market that is expected to reach about 100 billion dollars in the next decade.

Prince Edward Island soils, which are quite erodible (Burney and Edwards, 1996; Leyte et al., 1997), are severely affected by modern methods of potato (*Solanum tuberosum* L.) production; which take a heavy toll on soil physical properties (Edwards, 1988), cause severe erosion (Edwards et al., 1998) and diminish soil bio-diversity which is at the centre of soil organic matter dynamics (Gregorich et al., 1997; Beyer et al., 1999) — affecting aggregate strength and erodibility (Bryan, 1968; Angers and Carter, 1995). The seriousness of this problem is aggravated by the dominance of potatoes which is estimated at 46,667 ha. About 13% of this produces culled tubers which amounted to about 168,655 Mg in 1998.

Culled potatoes are seen as primary material for commercial composting (MacLeod et al., 1996) and an opportunity to replenish depleted soils in PEI. A modern procedure for commercial-scale potato composting has been developed (MacLeod et al., 1996) using potato culls. The resulting material showed general (though inconsistent) yield increases of about 7.5 Mg ha$^{-1}$ of potatoes (MacLeod et al., 1996) on a fine sandy loam soil (Podzol) (MacDougall et al., 1988). Knowledge is limited, however, of its effect on soil physical characteristics (under PEI conditions).

Potato production in PEI forms part of a 2- or 3-year rotational system with cereal and/or hay; and where straw becomes a waste product, it is available for use as mulch within the system. Mulching ranks highly as a cost-effective means of crop residue usage against soil erosion in annual row-cropping systems on sloping lands; and is at the centre of a resurgent soil conservation ethic in much of North America (Shelton et al., 1995). For cropping systems, like potatoes, that do not easily adapt to the application of residue material after the main crop is planted, and where mulching could be beneficial, it was considered useful to have some measure of its soil-conservation effectiveness.

The concept of mulch management as a systematic practice in row cropping on sloping fields is new to many farmers; and where it is attempted, farmers might expect to get the full soil protection benefits of a given quantity of mulch after tillage, as before it. Only no-till procedures could, however, be expected to achieve this in row crops (Shelton et al., 1995); but there is limited knowledge of its workability with potatoes.

The following study was done to measure the effect of (i) potato compost and (ii) straw mulching on soil loss and soil physical characteristics over 3 years using erosion plots. In addition, crop yield response was measured.

### 2. Materials and methods

This study of compost addition and straw application, 1996–98, was conducted as a single experiment using existing erosion plot facilities in the Wilmot watershed of PEI as described by Burney and Edwards (1994). The experiment comprised two replications (represented by two sets of erosion plots) of three treatments (represented, in each set, by three erosion plots): compost, straw mulch and a control. The results will be separately reported and discussed on the effect of compost and straw mulch. The test crop was ‘Russet Burbank’ potatoes and the test plots were typically managed for this crop. Blanket applications were made of N at 150 kg ha$^{-1}$, P at 150 kg ha$^{-1}$ and K at 150 kg ha$^{-1}$. The treatments were applied in the spring (late-May to early-June) of each year — post-planting, pre-emergence and pre-hilling. Yields were measured annually by harvesting the whole plot (4 m×22.1 m) in mid- to late-October.

Compost produced from potatoes, manure and sawdust in a large-scale composting facility at this Research Centre (MacLeod et al., 1996) was applied, fresh each year, at the rate of 15 Mg ha$^{-1}$ dry matter.

The mulch was surface-applied at approximately 4 Mg ha$^{-1}$ using barley (*Hordeum vulgare* L.) straw — the most common cereal by-product from potato rotations. It was partially incorporated during hilling. The principal soil physical characteristics assessed are shown in Tables 1 and 2. Soil compressibility properties comprised penetration resistance (using a recording penetrometer) and shear strength (using a
Table 1  
Effect of compost amendment on soil-loss characteristics of erosion plots\(^a\) of potatoes (mean values: 1996–98)

<table>
<thead>
<tr>
<th>Response</th>
<th>Sampling depth (cm)</th>
<th>Treatment(^c)</th>
<th>Compost</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss (kg ha(^{-1}) per year)(^b)</td>
<td>–</td>
<td>281 a</td>
<td>270 a</td>
<td></td>
</tr>
<tr>
<td>Bulk density (Mg m(^{-3}))</td>
<td>0–15</td>
<td>1.15 a</td>
<td>1.19 a</td>
<td></td>
</tr>
<tr>
<td>Soil penetration resistance (kPa)</td>
<td>0–15</td>
<td>416 a</td>
<td>450 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15–30</td>
<td>1126 b</td>
<td>1411 a</td>
<td></td>
</tr>
<tr>
<td>Shear strength (kPa)</td>
<td>0–15</td>
<td>65.4 a</td>
<td>72.1 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15–30</td>
<td>143.4 a</td>
<td>164.9 a</td>
<td></td>
</tr>
<tr>
<td>Soil moisture (kg kg(^{-1}))</td>
<td>0–15</td>
<td>246 a</td>
<td>230 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15–30</td>
<td>265 a</td>
<td>250 b</td>
<td></td>
</tr>
<tr>
<td>Aggregate stability (%)</td>
<td>0–15</td>
<td>76.1 a</td>
<td>73.4 a</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) 22.1 m \times 4.0 m.

\(^b\) Averaged over three trial years.

\(^c\) Treatment means in any row followed by the same letter are not significantly different.

Fig. 1. Relationship between shear strength and bulk density in (soil cores) induced by compost and mulching treatments.

Table 2  
Effect of straw mulching on soil-loss characteristics of erosion plots\(^a\) of potatoes (mean values: 1996–98)

<table>
<thead>
<tr>
<th>Response</th>
<th>Sampling depth (cm)</th>
<th>Treatment(^c)</th>
<th>Straw mulch</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil loss (kg ha(^{-1}) per year)(^b)</td>
<td>–</td>
<td>137 b</td>
<td>270 a</td>
<td></td>
</tr>
<tr>
<td>Bulk density (Mg m(^{-3}))</td>
<td>0–15</td>
<td>1.18 a</td>
<td>1.19 a</td>
<td></td>
</tr>
<tr>
<td>Penetration resistance (kPa)</td>
<td>0–15</td>
<td>477 a</td>
<td>450 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15–30</td>
<td>1501 a</td>
<td>1411 a</td>
<td></td>
</tr>
<tr>
<td>Shear strength (kPa)</td>
<td>0–15</td>
<td>70.3 a</td>
<td>72.1 a</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15–30</td>
<td>158.4 a</td>
<td>164.9 a</td>
<td></td>
</tr>
<tr>
<td>Moisture (kg kg(^{-1}))</td>
<td>0–15</td>
<td>243 a</td>
<td>230 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>15–30</td>
<td>248 b</td>
<td>250 b</td>
<td></td>
</tr>
<tr>
<td>Aggregate stability (%)</td>
<td>0–15</td>
<td>76.2 a</td>
<td>73.4 a</td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) 22.1 m \times 4.0 m.

\(^b\) Averaged over three trial years.

\(^c\) Treatment means in any row followed by the same letter are not significantly different.

3. Results and discussion

3.1. Compost

Soil loss from the compost-amended plots of potatoes was similar to that from the control plots (Table 1). Compost amendment significantly increased soil moisture and was 7% greater than it was for the control plots; and bears out the generally recommended farming practice of adding compost to benefit the soil during dry spells. The soil moisture increase was 10% in the final year of the experiment.

Compost had no effect on penetration resistance or shear strength in the root zone, 0–15 cm. Below the root zone, 15–30 cm, however, compost decreased penetration resistance by 20% (Table 1). This decrease reached 28% in the final year of the experiment; and, overall, might reflect the physical value of compost in keeping the subsoil open where the profile is natu-
rally more compact — while affording no advantage at the shallower depths which benefit from post-planting tillage. In assessing compost use in maize (*Zea mays* L.) production, Bazzoffi et al. (1998) found that this amendment prevented increases in penetration resistance under heavy vehicular traffic.

Aggregate stability was not affected by compost amendment (Table 1) when averaged over the experimental period. Variations in this characteristic may, however, go undetected with treatment (Bryan, 1999, personal communication) even where organic matter amendment is used (Siegrist et al., 1998). In the final year of this experiment, however, aggregate stability with compost increased 7%, and might reflect a cumulative effect of organic matter amendment (Beyer et al., 1999).

Compost amendment gave no significant yield advantage in total or marketable potato tubers (data not shown). The yield benefits that could be expected through increased soil moisture (Russell, 1973) did not materialise. Soil moisture showed a 70% positive correlation with total potato yield in this study. Bazzoffi et al. (1998) reported significant yield increases (though small) in maize by amending a heavy loam soil with urban-refuse compost; while MacLeod et al. (1996) found inconsistent yield responses of potato to potato compost on a fine sandy loam soil.

There seems to be little, arising from this study, to justify the use of compost as a soil amendment. Still, there is general expectation of productivity increases based on the soil-improvement merits of compost use (Russell, 1973). Such merits in this study were reflected in soil compressibility characteristics — which showed some interrelationship. Bulk density exhibited a strong ($p \leq 0.05$) positive relationship with shear strength measured on the soil cores ($R^2 = 0.835$) (Fig. 1). This may be viewed as a valuable relationship in view of a decade of attempts to employ simple methodology to develop indices characterising soil structure (Busscher et al., 1987; Van Ouwerkerk and Koolen, 1988).

### 3.2. Mulch

Soil loss was significantly affected by mulching, and decreased 49% with barley straw (Table 2) which could be expected on the basis of the surface-roughness factor (Ziegler and Sutherland, 1998). Straw mulching caused a significant increase in soil moisture which was 6% greater than it was for the control plots and similar to those amended with compost — bearing out the general, age-old principle of mulching for soil–water conservation (Russell, 1973; Tolk et al., 1999) while being a new concept in PEI potato production.

Aggregate stability and soil-compressibility characteristics were not affected (Table 2); and might suggest a general inability of straw, under the circumstances of this study, to influence variations that may generally be expected from mulch applications (Chaney and Swift, 1984; Angers and Recous, 1997; Beyer et al., 1999; Oyedele et al., 1999). Only upon data stratification did this study reveal significant changes in aggregate stability which, in the spring sampling, showed an increase of 9% — a likely reflection of the burst of rhizospheric organic activity associated with spring (Coote et al., 1988; Ambus and Jensen, 1997; Angers and Recous, 1997).

There is no question that mulching was effective in erosion control, having reduced soil loss to only half of what it was from unmulched plots. These results confirm a basic expectation (Frame et al., 1992; Parsons et al., 1994), and are, thus, not surprising at any level of agronomic or hydrologic scrutiny. What comes into question, however, is the practical worth of this procedure in a potato culture like PEI’s. Not only is it tedious to spread the mulch post-planting; but just how much of it will stay on the surface under windy conditions before plant emergence or hilling, is another matter. In other related studies using simulated rainfall, surface-applied straw was four times as effective as the same mass of surface-incorporated straw in controlling soil loss in potatoes (Parsons et al., 1994).

Straw mulching in the present study had no effect on yield (data not shown). Historically, yield responses with mulching have been variable, and have been tied negatively to nitrogen demobilisation (Beyer et al., 1999) or positively to improved soil moisture status — which increased significantly with mulching in this study. Tolk et al. (1999) and Unger (1986) saw maize yields vary in both directions, while definitive increases were variously reported by Lal (1974, 1995) and Wicks et al. (1994) — attributed to increased soil water contents due to reduced evaporation.
3.3. Place of compost and mulch in potato agronomy

3.3.1. Compost

Commercial-scale opportunities for compost have recently changed the scope of local thinking both from the input (supply) and output (use) ends of farm practice. Regardless of the results of this study, composting stands out as the obvious sink for potato culls fed by an industry that shows an annually increasing capacity for output, and an increase in the acreage of depleted potato land.

What is questionable about the commercial use of potato (or any other) compost is its place in an inorganic potato culture, like PEI’s, that has traditionally ignored large-scale composting. Practicality and practicability are integral to its worth. Spreading compost is tedious because of its bulk and its imposition on the farming schedule.

Even if practicable, how well could compost usage replace agronomic intervention by high-fibre crops, and reduce the need for long rotation cycles or grass fallows? What proportion of the land under potatoes could be adequately supplied with compost? How limited might compost quantities become as new markets afford lucrative opportunities for potato culls; or as improved cultivars or production techniques (including added nutrients) reduce the yield of these culls? How long will it take for compost amendments to reach maximum effectiveness on commercial potato fields? Maximum soil stability benefits could not normally be expected from a sod, for example, within 10 years (Kay, 1990). Thus, if benefits are to accrue, how long would they last once the field is returned to intensive potato production?

Intensive tillage rapidly degrades the physical state of the soil (Bauer and Black, 1981; Chan and Mead, 1989).

3.3.2. Mulch

Assuming that mulching potatoes has intrinsic agronomic value, farmer adoption on a commercial scale might be a hard sell for extension agents. The level of adoption might well be determined by the level of requirement for surface cover, or limited by the maximum amount of mulch material that the farmer could handle while striving for optimum seedbed conditions. Optimum particle size of the mulch material might be an important consideration where it is critical to increasing soil microbial activity (Ambus and Jensen, 1997; Angers and Recous, 1997).

Any farmer-adoption strategy that is used must consider that, while it takes reduced tillage to achieve maximum residue-cover effectiveness for a row crop (Shelton et al., 1995) like potatoes, reduced tillage is agronomically inimical to high tuber yields (Russell, 1973) and wide acceptance is, therefore, unlikely.

4. Conclusions

Compost amendment reduced subsoil compressibility, as reflected in reduced penetration resistance values, and could be useful in keeping-open compactible soil. It increased soil water content but did not affect crop yield; and increased aggregate stability, but not until the third year of the experiment. Straw application did not affect potato yield in any of the three trial years, although negative effects are variously reported for similar circumstances. As with compost amendment, straw mulching increased water content — which has the potential to be beneficial in dry years.

Acknowledgements

The authors greatly appreciate the skilled assistance of Harry Younie; and, with sadness, observe the recent death of Prof. Dr. Gerold Richter. His dedicated contribution is acknowledged to this study and to other soil erosion studies in Prince Edward Island, Canada, over the last decade through the Canada–Germany Cooperation Agreement in Science and Technology.

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