Agricultural & Environmental Letters

Research Letters

Core Ideas

- The Solvita compost gel system was well calibrated with calcium carbonate C.
- The Solvita compost gel system was highly correlated to the standard pressure calcimeter method.
- The Solvita compost gel system is an alternative method for inorganic C determination.

Abstract: Determination of inorganic carbon (IC) as calcium carbonate is important for soil fertility and soil health assessments in alkaline soils. Methods have been developed to determine IC, including the widely used pressure calcimeter method. We compared 19 alkaline soils using the pressure calcimeter method and the Solvita gel system, which was recently developed to measure CO₂ respiration. Results from the study indicated calibration curves for the Solvita gel system could be developed within an approximate range of 1 to 30 mg IC. Comparison of the Solvita gel system with the pressure calcimeter resulted in a near 1:1 relationship, where slight overestimation occurred when IC was less than 13 g kg⁻¹ and slight underestimation above this level. The results of this study indicate the Solvita gel system can be considered as an alternative method for IC determination.

Abbreviations: DCR, Digital Color Reader; IC, inorganic carbon.

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if the Solvita gel system could produce comparable results as compared to the traditional pressure calcimeter method and thus be considered as a method for use in soil testing.

**Materials and Methods**

**Calibration Curve for Pressure Calcimeter and Solvita Gel System**

A laboratory study was conducted to compare the efficiency of measuring CaCO$_3$ using pressure calcimetry and the compost maturity Solvita gel system. All samples were analyzed in duplicate and averaged. A calibration curve was developed based on the methods of Sherrod et al. (2002) and Fonnesbeck et al. (2013). Standards were prepared using reagent grade CaCO$_3$ at amounts of 1.2, 6, 12, 18, 24, and 30 mg IC.

Calcimeter standards were analyzed using a 60-mL gas-tight vial, where 5 mL of distilled water was added. Vials were then sealed and 2 mL of 6 M HCl containing 3% (w/w) iron (II) chloride was injected through a septum. Measurements were taken after 2 h via a pressure transducer (Setra 280E, Setra Systems Inc.). A linear calibration curve was developed using the data from the pressure transducer.

The Solvita compost maturity gel system was used to develop the calibration using high CO$_2$ (compost) Solvita paddles. Standards were the same as above where a 473-mL wide-mouth Mason jar with an 86-mm dome lid was used (Rogers et al., 2017). Five milliliters of distilled water was added, and a 4-mL sample cup with 2 mL of 6 M HCl containing 3% (w/w) iron (II) chloride was placed inside each jar with a Solvita high CO$_2$ (compost) paddle. The paddle was lifted using a 5.7-cm plastic test tube to avoid the paddle touching the acid/water mix. The containers were then capped, the sample cup tipped over, and the acid swirled. In preliminary studies, the Solvita gel system required 6 h to equilibrate (data not shown); thus, this timeframe was used for extractions. After 6 h, the containers were opened and each paddle was analyzed under the high CO$_2$ (compost/manure) and low CO$_2$ (CO$_2$ burst) modes on a Solvita Digital Color Reader (DCR) Multi-Mode Unit (Woods End Laboratories). As IC measurement is separate from developed methods for the DCR, we recorded the color reading for our analyses. The calibration curve was fit to determine the amount of IC in the soil using the high CO$_2$ and low CO$_2$ values. Finally, these calibrations were used to determine the IC content of 1-g soil samples.

**Soil/Standard Description and Characterization**

The tested soils in the study include a mix of North American Proficiency Testing (NAPT) program standards and samples taken from across southern Idaho (n = 19) (Table 1). During preliminary experiments, we determined that the DCR was unable to quantify IC below approximately 1 mg and was not reliable beyond 30 to 36 mg IC.

**Statistical Analyses**

Linear regression models were used to fit the millivolts or Solvita color reading (high and low reading) as a function of IC content of the standards. Pearson correlations and linear regressions were performed to compare the IC content of the standards. Pearson correlations and linear regressions were performed to compare the IC content of the standards.

**Table 1. Physicochemical properties of soils and North American Proficiency Testing Program (NAPT) samples used in the study. Samples 1–4 were from the NAPT where year-sample numbers are reported.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Soil texture/series</th>
<th>Sample/taxonomic classification</th>
<th>Soil pH</th>
<th>Inorganic C (Calcimeter)</th>
<th>Inorganic C (Solvita paddle)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Sandy loam</td>
<td>NAPT-2009-115</td>
<td>7.9</td>
<td>2.2</td>
<td>3.4</td>
</tr>
<tr>
<td>2</td>
<td>Silty clay loam</td>
<td>NAPT-2016-103</td>
<td>8.0</td>
<td>12.4</td>
<td>14.3</td>
</tr>
<tr>
<td>3</td>
<td>Loam</td>
<td>NAPT-2017-104</td>
<td>7.5</td>
<td>3.1</td>
<td>5.5</td>
</tr>
<tr>
<td>4</td>
<td>Clay</td>
<td>NAPT-2018-115</td>
<td>8.1</td>
<td>7.3</td>
<td>8.1</td>
</tr>
<tr>
<td>5</td>
<td>Portneuf SiL</td>
<td>Coarse-silty, mixed, superactive, mesic Durinodic Haplocalcids</td>
<td>8.2</td>
<td>21.8</td>
<td>19.4</td>
</tr>
<tr>
<td>6</td>
<td>Power McCain complex</td>
<td>Power: Fine-silty, mixed, superactive, mesic Xeric Calcigandids; McCain: Fine-silty, mixed, superactive, mesic Durinodic Xeric Calcigandids</td>
<td>8.1</td>
<td>1.8</td>
<td>3.0</td>
</tr>
<tr>
<td>7</td>
<td>Harston fine sandy loam</td>
<td>Coarse-loamy, mixed, superactive, calcareous, frigid Xeric Torriulventus</td>
<td>8.2</td>
<td>13.2</td>
<td>13.7</td>
</tr>
<tr>
<td>8</td>
<td>Rad FsL</td>
<td>Coarse-silty, mixed, superactive, mesic Durinodic Haplocambids</td>
<td>8.3</td>
<td>21.9</td>
<td>21.0</td>
</tr>
<tr>
<td>9</td>
<td>Portneuf SiL</td>
<td>Coarse-silty, mixed, superactive, mesic Durinodic Haplocalcids</td>
<td>8.3</td>
<td>16.6</td>
<td>15.4</td>
</tr>
<tr>
<td>10</td>
<td>Portino SiL</td>
<td>Coarse-silty, mixed, superactive, mesic Haplocalcids</td>
<td>8.1</td>
<td>15.9</td>
<td>14.3</td>
</tr>
<tr>
<td>11</td>
<td>Pancheri SiL</td>
<td>Coarse-silty, mixed, superactive, frigid Xeric Haplocalcids</td>
<td>8.1</td>
<td>21.8</td>
<td>20.3</td>
</tr>
<tr>
<td>12</td>
<td>Picabo SiL</td>
<td>Coarse-silty, carbonatic, frigid, Oxyaquic Calcixerolls</td>
<td>8.1</td>
<td>21.1</td>
<td>21.3</td>
</tr>
<tr>
<td>13</td>
<td>Potell SiL</td>
<td>Coarse-silty, mixed, superactive, calcareous, frigid Xeric Torriorthents</td>
<td>8.3</td>
<td>9.5</td>
<td>9.8</td>
</tr>
<tr>
<td>14</td>
<td>Declo loam</td>
<td>Coarse-loamy, superactive, mesic Xeric Haplocalcids</td>
<td>8.1</td>
<td>12.9</td>
<td>12.8</td>
</tr>
<tr>
<td>15</td>
<td>Declo loam</td>
<td>Coarse-loamy, superactive, mesic Xeric Haplocalcids</td>
<td>8.2</td>
<td>11.9</td>
<td>14.1</td>
</tr>
<tr>
<td>16</td>
<td>Declo loam</td>
<td>Coarse-loamy, superactive, mesic Xeric Haplocalcids</td>
<td>8.3</td>
<td>12.6</td>
<td>12.8</td>
</tr>
<tr>
<td>17</td>
<td>Declo loam</td>
<td>Coarse-loamy, superactive, mesic Xeric Haplocalcids</td>
<td>8.2</td>
<td>5.3</td>
<td>6.9</td>
</tr>
<tr>
<td>18</td>
<td>Declo loam</td>
<td>Coarse-loamy, superactive, mesic Xeric Haplocalcids</td>
<td>8.4</td>
<td>15.7</td>
<td>14.8</td>
</tr>
<tr>
<td>19</td>
<td>Kucera/Ririe complex</td>
<td>Kucera: Coarse-silty, mixed, superactive, frigid Calcic Pachic Haploxerolls; Ririe: Coarse-silty, mixed, superactive, frigid Calcic Haploxerolls</td>
<td>8.1</td>
<td>6.1</td>
<td>7.5</td>
</tr>
</tbody>
</table>
values determined on the soils via the pressure calcimeter and Solvita gel system. All analyses were performed in Sigma Plot 13.0 (Systat Software, 2014).

Results and Discussion

The pressure calcimeter calibration regression produced a linear fit with $R^2 = 0.99$ (Fig. 1a). High (Fig. 1b) and low (Fig. 1c) color calibrations generated positive and negative polynomial fit with an $R^2$ of 0.99 and 0.98, respectively.

Soil sample values were calculated based on the calibration of IC to millivolts, high color readings, and low color readings, respectively (Table 1). Visual examples of the range of paddle results are shown in Fig. 2. Correlations indicated that pressure calcimeter IC was strongly related to both the high and low paddle readings where $r = 0.99$ for both (data not shown). Regression analysis further confirmed the goodness-of-fit as noted by an $R^2$ of 0.98 and 0.97 for the IC content determined by the high and low color paddles as compared to the IC content determined via the pressure calcimeter, respectively (Fig. 3). Compared with the calcimeter method, the gel system tended to slightly overestimate IC content when IC was less than 13 g kg$^{-1}$ and underestimated above this IC level. However, within the range of the tested samples the difference from the 1:1 line was less than 1 to 2 g kg$^{-1}$ at all points.

Conclusions

The Solvita gel system was strongly correlated with the pressure calcimeter IC in the soil samples used in this experiment. The Solvita gel system could be utilized with little change to existing DCR devices; however, a specifically designed method in the DCR would allow less effort by users and more accurate readings, and could potentially
be adjusted to provide a wider range of analysis. Use of the Solvita paddles could reduce hazards involved in IC analysis and provide a simple and convenient way to analyze IC in soils.

**Conflict of Interest**
The authors declare no conflict of interest.

**Acknowledgments**
We would like to acknowledge Grant Loomis and Erin Thurgood for their assistance.

**References**


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