SOLVITA®

SOP Version: 2019:2.1
DCR Model 12.3

INSTRUCTIONS
Natural Soil Respiration
Users Guide for Soil Master and Field CO_2 Test

The release of carbon dioxide from fresh soil due to biological activity is a natural phenomena that occurs over a very wide range of temperature and moisture conditions. The *Solvita® Field Test and Soil Master* are protocols which enable testing fresh, undisturbed soil respiration. The *Soil Master* Kit includes material and equipment for soil sampling and preparation designed to obtain the best results using minimal disturbance.

This application of field respiration testing is meant to reveal soil biological activity under natural, less-disturbed conditions. This form of respiration is often called "basal". It differs from laboratory methods that include drying, grinding, sieving and remoistening. Soil testing using the Field Kit and Soil Master approach is intended to represent "steady-state" which is considered normal, background status associated with ordinary soil functioning. The results may be described as "field respiration" or "biological activity of fresh soil".

Soil Health and Benefits for Crop Growth: Measuring the quantity of CO_2-output from soil is a means to assess biological functioning, a vital expression of *soil health.* No other type of test more accurately and completely expresses soil biological functioning as does CO_2 respiration, since a common trait of all micro and macro-soil organisms is metabolic respiration of carbon-containing compounds. Properly managed soils should show appreciable rates of respiration under moist, warm conditions. In addition, plant photosynthesis is dependent on available CO_2 and therefore the quantity of carbon dioxide emitted from soils directly impacts plant growth by supplying CO_2 in close vicinity of the plant surfaces. Thus respiration may provide essential crop information.

STANDARDIZING: When using Solvita® with freshly sampled, as-is soils from the field the actual soil temperature and moisture play a key role. It is best to conduct comparisons over time under similar conditions and by noting actual external conditions at the time of the sampling. Correction factors for soil temperature are shown in Table 2.

Tools Mentioned in this Manual: This guide refers to certain recommended tools including a soil knife, field-scale, sieve, brush and DCR. These tools are all included in the Soil Master Kit or are available by contacting Woods End Labs or other soil engineering firms.

Updates in this Ver 2.1 Manual: The soil quantity employed in the tests is adjusted based on new information for the most uniform results, see page 2, #2 "Weigh Sample".

MEASURING RESPIRATION
As-is Soil Removed from Field

Take sample with trowel or knife

Sieve sample to remove debris and gently homogenize

Optional: weigh sample:
50 g for 265 cc jar or
90 g for 475 cc jar

Insert probe

For more soil increase jar size

1. **SAMPLING:** Soil should be freshly sampled prior to the test under normal, field-moist conditions. An ideal soil sampler is a soil-knife (pictured) which also indicates depth on the blade. A trowel or spade is also acceptable. Soil-corers are not advisable since they compress and create a shear-surface which inhibits natural air diffusion. With a knife or trowel first make a cut to the desired depth, discard the first slice, then cut down the side of the soil trench and place soil onto sieve. Multiple sample points (minimum 12) should be taken across a uniform field.

   SOIL TEMPERATURE: Use any soil thermometer to record actual field soil temperature when sampling. Insert to 3" (7cm) for 6" (15 cm) deep samples. This result is used to adjust between room temperature and actual field temperature and as a reference in the on-line field calculator (see Table 2).

   SIEVING HOMOGENIZATION: A 6 mm (1/4") sieve or a garden-soil sieve is one of the best means to prep the soil. Handfuls of soil are gently rubbed through the screen. No further processing is required. This step homogenizes soil and helps remove stones and plant debris without damaging the sample. If soil is too wet for testing, it will also be difficult to rub through a sieve.

   SOIL MOISTURE: The Field Kit and Soil Master procedure is intended to show respiration *under natural field conditions* and moisture is not adjusted. An ideal sampling time is 2-5 days after a normal rainfall or irrigation event after water has infiltrated evenly - this will be near *field capacity*. If soil is sampled too dry or too wet, it may produce *lower* respiration.

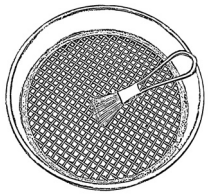
2. **WEIGH SAMPLE INTO SOLVITA® JAR:** It is advised to weigh the sample or to use a standard volume scoop for all samples. **NEW: For 8 oz (265 cc) jars use 50 g (1.5 oz) moist soil. For the new Standard Solvita Jar (1 pt or 475 cc) use 90 g (3 oz).**

3. **NEW: VARIABLE SIZE TESTS**: The Solvita test is normally conducted in jars supplied in the kit, either 8 oz (265 cc) polystyrene with 50 g soil or the new Standard Solvita Jars (475 cc), both fitted with rubber seals. Ball canning jars may also be used if they have rubber seals. The test may be performed with larger quantities of soil so long as the jar air size is proportional to the soil (see section 4. and NOTE on next page).

C T I O N S

Test Period is 24 hours

Soil sieve fits into top of standard 5-quart pail



Use a brush for cleaning between sampling.

Results are read at 24hr using either the DCR Field Unit (Green) or the Multi-Mode DCR (Yellow) using the ALT Mode key.

4. **VOLUME ADJUSTMENT (optional):** Different quantities of soil may be used in the test and still obtain equivalent Solvita results by simply adjusting the total volume accordingly, as shown below comparing Column (1) and Column (2 or 3).

(1) SOIL weight in grams	(2) US Jar Size	(3) Metric Jar Size
50	Solvita (8 oz)	265 cc
90	PINT **NEW:** Solvita Standard Jar	475 cc
180	QUART	925 cc (1 liter)
370	1/2 GAL	1900 cc (2 liter)

5. **START THE TEST:** The test starts when the Solvita CO_2 probe is inserted into the moist soil in the jar. Tear open the Solvita foil pouch and carefully remove the probe by the handle. *Avoid touching the gel surface, and don't allow soil to touch it.* Push the tip of the probe into the sample so the probe stands erect. Avoid jostling the jar. Screw the lid on tightly and record the start time. Keep the jar at a constant temperature (Interpretation in Table 1 is based on 70ºF/20ºC). See Table 2 for conversion factors.
6. **Use of Sieve inserted into a pail:** Standard soil sieves such as the one used in Soil Master Kit also fit into a common 5-quart pail obtained at most hardware stores. This provides a convenient means to handle preparation of soil.
7. **Cleaning the Wire Sieve:** Do not wash in between sieving, but use brush to clean. A steel wire brush is enclosed with the *Soil Master Kit* for easy cleaning.
8. **READ THE PROBE:** At 24 hours remove probe from the jar. Turn on the DCR Field Unit (Green Unit) or the Multi-Mode DCR (Yellow) in ALT Mode and insert probe gel side up. Press the read button to display color number (matching the visual color key) and the quantity of CO_2. For interpretation use the color number and see *Table 1*. An on-line calculator is available at *solvita.com/soil/basal-co2-guide*

NOTE: **Area and Size Considerations**: Solvita probes respond to concentration of CO_2 in the air volume (headspace + pore space). This is quantified based on the *Ideal Gas Law* (PV = nRt, assuming 1ATM at 20°C and ~20% water). If the air volume:solid mass ratio is held constant Solvita will lead to similar results regardless of the quantity of soil.

INTERPRETING CO_2 RESPIRATION

The following table shows a soil biological activity curve in the range expected for moist cultivated soils measured at ambient temperature of 20-22°C (68-72°F). In situ (in-field) results may differ by a temperature factor shown in Table 2.

Table 1: Interpretation - Respiration in Test Jar at 20-22°C (68-72°F)

A	**Color 0 - 1.0 Blue-Gray**	**Color 1.0 - 2.5 Gray-Green**	**Color 2.5 - 3.5 Green**	**Color 3.5 - 4.0 Green-Yellow**	**Color 4.0 - 5.0 Yellow**	**Color 5.0 - 6.0 Bright Yellow**
B	Extreme LOW ACTIVITY Associated with extremely depleted soils	LOW ACTIVITY Marginal biological activity with low OM (organic matter)	MEDIUM-LOW ACTIVITY Medium active and may be accumulating OM	IDEAL ACTIVITY Active microbe population and good OM supply	MED- HIGH ACTIVITY Very active biologically with very high OM turnover	VERY HIGH ACTIVITY High biological activity with excellent supply of OM
C	**ESTIMATED EMISSIONS (FLUX) OF CO_2-C as kg/ha or lb/acre**					
	0.5 - 1	**1 - 5**	**5 - 15**	**15 - 25**	**25 - 60**	**60 - 160**
D	**INTERNATIONAL EMISSIONS (FLUX) OF CO_2 as grams / m^2 / day**					
	0.2 - 0.4 g/m^2	**0.4 - 2.0**	**2.0 - 6.0**	**6.0 - 10.0**	**10 - 25**	**25 - 65**

Soil Activity Curve

A: Color Reading of gel (this matches the official Solvita visual color key).

B: Suggested guideline to describe biological soil condition of cultivated soils.

C: Standard units to report respiration (see also Table 3, column D). Units are CO_2-C. Results depend on a variety of factors such as depth of sampling, soil temperature and field-moisture.

D: International Metric Units based on CO_2. For row C the units are CO_2-C (i.e as carbon). Use 3.7 to get to CO_2 (carbon dioxide) from CO_2-C or 0.273 to go from CO_2 to CO_2-C.

Table 2: Conversion from room temperature (70F/20C) to actual temperature as measured in the field at sampling*

Actual Temp:	40°F / 5°C	50°F / 10°C	60°F / 15°C	70°F / 20°C	80°F / 30°C
Divide by to get actual field result	**4**	**2**	**1.5**	**1**	**0.5**

Example of using Table 2: If soil temperature when sampling is 60°F/10°C, and you ran the test at standard 70°F/20°C, then take the CO_2-C lb/a result, divide by 1.5 then go to Table 1. See Solvita.com for the on-line calculator which makes continual adjustments for respiration at any given temperature. Conversely use the index to convert CO_2 rates performed at non-standard results back to standard 70°F/20°C data.(*https://solvita.com/soil/basal-co2-guide*)

PLANT GROWTH & SOIL CO_2 RESPIRATION

Measuring the quantity of soil CO_2 efflux is a means to assess soil biological functioning. In addition to providing an index of soil activity, CO_2 rates are important for plant growth. Plant photosynthesis may be rate-limited by the availability of CO_2 in the immediate vicinity of the plant surfaces during active assimilation periods. Therefore the quantity of carbon dioxide emitted from soils can directly impact plant growth. Table 3 illustrates the amount of CO_2 associated with crop yields and the equivalent volume of air needed to supply CO_2 without soil respiration and the soil respiration to meet these crop photosynthesis needs.

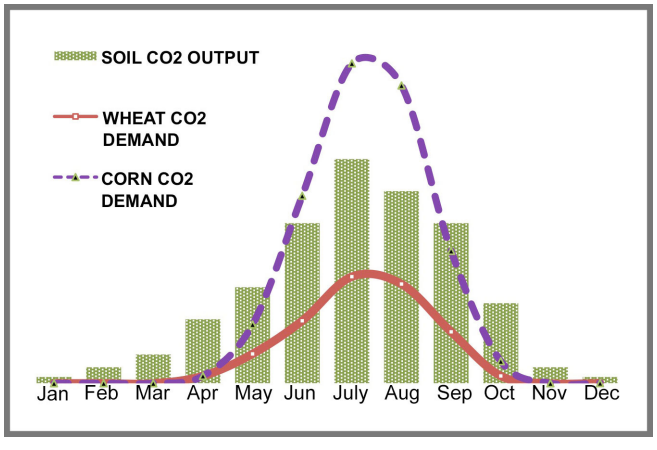
Table 3: CO_2 NEEDED FOR CROP GROWTH

	A	B	C	D*
CROP	Estimated dry yield as ton/a (*x* 2 = t/ha)	Avg. daily CO_2 Uptake during full season growth lb/a (x 1.12 = kg / ha)	Cubic Quantity of air per a or ha area above crop required to supply needed CO_2	Solvita Soil CO_2-C Respiration Rate which covers C-Need
Wheat	2.5	150	11 cubic	40
Alfalfa	2	130	10	35
Fodder Beets	6.5	440	35	119
Soybean	1.5	90	6.8	24
Corn	5.5	350	27	95

* Column D equals Column B divided by 3.7 converting CO_2 to CO_2-C as used in the Solvita test.

In high functioning ecosystems (such as tropical forests) virtually all the CO_2 and nitrogen released due to soil respiration is utilized and recycled by the canopy. If CO_2 is limiting then nutrients will be inefficiently used. Conversely, if nutrients are limiting, than photosynthesis may be undersaturated, CO_2 supply is inefficient and escapes to the atmosphere. Performing one respiration test does not represent all conditions, and should be repeated to capture the behavior at other times.

Crop CO_2 Demand in Relation to Soil Evolution



This hypothetical graph shows the CO_2 output of an average PA dairy-farm soil. *Adapted from: SCAN (Soil Climate Analysis Network) 2012 Data, Central-PA, USDA-NRCS Modified using SCAN soil temperatures to model CO_2 output.*

TIPS FOR SOLVITA® FIELD SOIL TESTING
How to Obtain the Best Results

1. Soil Factors: Measuring soil respiration in the fresh field samples with minimal disturbance is dependent on variables which are spatially limited and dependent on temperature and moisture. When using the field test to make comparisons between fields and farms it is advisable to sample under similar conditions. If comparing fields from year-to-year it is also advisable to sample when environmental conditions are known to be comparable.
2. Use of the DCR Field Unit: The Digital Color Reader (DCR) is a sophisticated mini-spectrometer that is pre-calibrated to Solvita conditions. The principle is to convert color results to CO_2 concentration and report either as mg/kg or mg/liter or kg/ha as CO_2-C. To convert to lbs CO_2 multiply by 3.7.
Free Firmware updates are available at *solvita.com/digital-color-reader/*
3. User-Calibration: Solvita results are calibrated for the standard volume of soil + air or headspace in a Solvita® jar or as shown in Section 4 on page 3. These relationships have been updated in Nov 2018 to obtain the best results. If users wish to calibrate to other conditions, the Solvita color number (optical density unit) should be used as the dependent variable.
4. Metric vs Imperial units: To change the Green Field DCR between reporting units hold down the READ button for at least 10 seconds, release the button, then turn device off and repower.
5. DCR Software: Solvita software is available for recording the DCR readings directly into a .csv file when attached by USB cable to a PC. The software is included in new purchases of a DCR. The DCRs possess internal data storage capability, allowing uploading of all results from the unit at a later point.
6. On-Line Calculator for Solvita Field Test results: An on-line calculator that estimates annual soil functioning based on test parameters may be found at S*olvita.com/soil/basal-co2-guide/*
7. Lab Version of Solvita Test: A soil lab Solvita test called CO_2-Burst is available from many commercial soil labs and is performed on pre-dried and re-moistened soil samples and requires the yellow multi-mode DCR. For commercial soil labs, see soil lab map at *Solvita.com/soil/map/*
8. Pouch Longevity: The Solvita probes are specially packaged and sealed to assure freshness for an extended period. The box of probes should be removed from the field case and stored in a cool location when not in use. The probes should not be allowed to freeze.
9. Technical Support: Woods End Laboratories is committed to see the Solvita test used properly to obtain meaningful and valuable soil results. To this end we are happy to take inquiries by email (solvita@woodsend.com) and will respond as soon as possible.

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