Mathematical model for calibration of CO2 released by soil microbial respiration captured by passive sampler in field conditions

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Introduction:

Soil respiration is an important indicator of soil health. It signals the level of microbial activity and the soil health functionality through the ability of the soil's microbial community to use plant residues, mineralize and make nutrients available to plants and other organisms, and to store nutrients over time.

Microbial activity respiration measurement:

We have used the common, rapid, low cost, and integrative measure of general microbial activity level developed by Cornell University (reference 2) using an alkali trap "passive sampler" for measurement the soil microbial respiration activity by capturing the evolved CO_2 as a waste product of respiration after application of PrimAgro (the designation of products containing a nutrient component *plus* dormant beneficial bacterial strains of *Bacillis spp).*

Measurements of CO_2 capture was based on the reaction between KOH and CO_2 to form K_2CO_3 and water as per the following equation:

$$CO_2 + 2\,KOH \rightarrow K_2CO_3 + H_2O$$

Method:

20 ml of 0.5 M of KOH liquid added in a glass jars, hung inside the passive sampler (sealed PVC chamber). It was then left in for 24 hours to allow KOH to absorb the CO_2 and formation of K_2CO_3 and water. After 24 hours, the liquid was poured back into vials and sent to the lab for measurement of the electrical conductivity (EC). The differences in EC between the control treatments and other treatments of microbial components present the quantity of CO_2 released by soil microbial activity and formation degree of K_2CO_3.

Figure 1. Passive sampler for CO_2 capture spread across a research field at AgroLiquid (2017).

Data development:

a. To accurately determine the changes of KOH reaction with CO_2 and formation of K_2CO_3, resulted by CO_2 capture, the EC of solutions measurements carried in µS/cm.

b. A calibration procedure was conducted on standard 0.5 M of K_2CO_3 with 24 gradual incremental volumes from 0.051 ml up to 2.0 ml and their EC values reported between 69- 2255 µS/cm which fit the range of the experiment treatments' measurements lied between 600- 1400 µS/cm.

c. Based on the calibration procedure, the concentrative properties of K_2CO_3, and our measurements, we were able to develop four sets of parameters: Mass of K_2CO_3 (%), their electrical conductivity in ms/cm, density of K_2CO_3 solution in g/cm^3, and K_2CO_3 solution molarity; as shown in Table 1.

d. The values of calibration expressed in molar concentrations and their mass concentrations were integrated (Figure 2) and a math equation was developed as a model to calculate the CO_2 released by soil microbial activity respiration in actual quantities of CO_2 emission in ppm (i.e., EC values converted to molar weight and calculated as actual molar weight of captured CO_2 in ppm), as follow:

y = 2E-05x2 + 0.0045x + 0.0035

Where: Y = actual loss of CO_2, X = Mass concentration of K_2CO_3 (%) vs. solution molarity concentration (c/mol L^{-1}).

Table 1. Concentrative properties of K_2CO_3 developed mathematically to fit with the interval of the experimental measurements.

Mass of K_2CO_3 (%)	%	0.007	0.017	0.031	0.063	0.125	0.25	0.5	1.0	2.0	5.0	10.0	15.0	20.0	25.0
Electrical conductivity	mS/cm	0.179	0.35	0.69	1.23	2.1	4.0	7.0	13.6	25.4	58	109	152	188	223
Density of solution in g/cm^3	ρ/g cm-3	0.999	0.999	0.999	1.0	1.0	1.0	1.003	1.007	1.016	1.044	1.09	1.139	1.189	1.245
Solution molarity	c/mol L^{-1}	0.0005	0.001	0.002	0.005	0.009	0.018	0.036	0.073	0.147	0.377	0.789	1.236	1.722	2.252

Measurements, results, and discussion

Experiments were conducted during the summer of 2017 for evaluation of the microbial activity respiration levels determined by measuring the amount of CO_2 generated in the specific combinations (N-P-K PrimAgro liquid fertilizers) of beneficial microbes (*Bacillus subtilis and Bacillus methylotrophicus bacteria)* contains 401 million total colony forming units per gallon (4.01x10^8 total CFU/gallon) and carbon compounds compared with non-microbial component product, applied to corn.

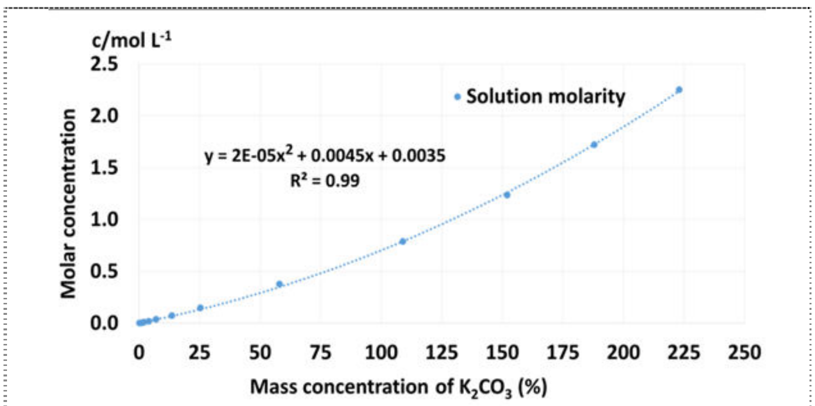

Figure 2. Mass concentration of K_2CO_3 (%) correlated with molar concentration in (*c/mol L^{-1}*) to calculate the CO_2 released by soil microbial activity respiration in actual quantities of CO_2 emission in ppm.

To validate the dynamic function of the microbial component products measured by CO_2 capture, soil samples taken periodically at 0-6” during the crop growing season

The CO_2 capture were measured in AgroLiquid’s laboratory and the soil samples were analyzed by the Haney Test (also known as the Soil Health Test) at Haney Laboratory for comparison, as part of the soil health analyses package. Figure 3 and Table 4 are clearly showing the impact of microbial products compared with non-microbial.

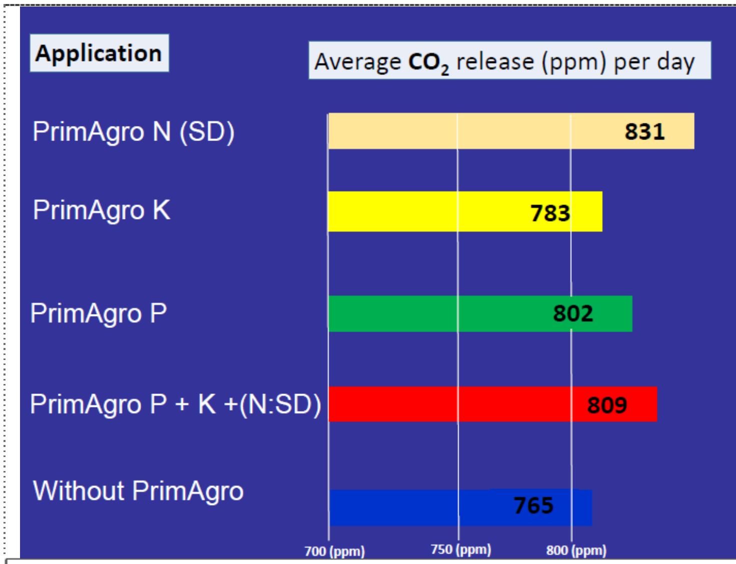

Figure 3. Increased values of carbon dioxide (CO_2) released after application of the microbial component products indicate an increase of soil microbial activity.

Table 2 shows the soil respiration 1-day CO_2-C (carried in Haney Laboratory) as a measure of the microbial biomass in the soil. Microbial biomass is one of the most important numbers in this soil test procedure related to soil fertility and the potential for microbial activity. Numbers are reported in ppm (the same as generated by mathematical method) the amount of CO_2-C released in 24 hours from soil microbes after soil has been dried and rewetted (as occurs naturally in the field).

Table 2. Results of soil heath measurements conducted at Haney Lab. of soils sampled on July 17, 2017 in AgroLiquid research farm.

Treatments	Soil Health Measurements				
	1-day CO_2-C	Organic C	Organic N	Organic C: N	Soil Health Calculation
P + K + (N: SD)	55.5	92.9	29.2	3.2	7.7
P + K + Fulvic Acid + (N: SD)	80.0	80.3	38.5	2.1	10.0
PrimAgro P + K (N: SD)	96.1	99.7	2.7	2.7	12.2
P + K + (N: SD)	61.0	113.6	35.6	3.2	8.7
Potash + N + P	58.0	87.6	40.7	2.2	8.0

Conclusion:

The method of CO_2 capture and the measured values of CO_2 (in ppm) developed by the mathematical model were validated with the Haney Test. Therefore, the CO_2 method provided actual quantification of CO_2 emissions in ppm for the applied microbial components and helped to run this model on a large scale with different soil conditions and variable environment.

References:

1. S.J. Del Grosso, W.J. Parton, A.R. Mosier, E.A. Holland, E. Pendall, D.S. Schimel, D.S. Ojima. Modeling soil CO_2 emissions from ecosystems. Biogeochemistry, 2005, Volume 73, Number 1, Page 71.
2. Comprehensive Assessment of Soil Health Laboratory. Soil Health Manual Series. Cornell University School of Integrative Plant Sciences. The full manual is available at: bit.ly/SoilHealthTrainingManual.