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RESEARCH ARTICLE

Manure-based slurry film promotes reduced fertilizer input through microbially-mediated nutrient activation mechanism and its life cycle assessment

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SUPPLEMENTARY MATERIALS

1 Soil sampling method

1.1 Sampling point layout

As we discussed in the main text, only middle column maize was count to avoid boundary effect, the soil of this part was rectangle, we use diagonal point layout method thus the sampling point was distributed in Fig. S1. 16 points total was arranged, and collecting 0–10 cm and 10–20 cm of cultivated soil layer at each point respectively. We mixed point 1, 2, 3 and 4 together as part 1,

point 5, 6, 7 and 8 together as part 2, point 9, 10, 11 and 12 together as part 3, point 13, 14, 15 and 16 together as part 4. We mixed 2 samples of each part together for total nitrogen, olsen-P, olsen-K, and organic matter content, while the soil aggregates of each part was tested with 010 cm and 10–20 cm, respectively.

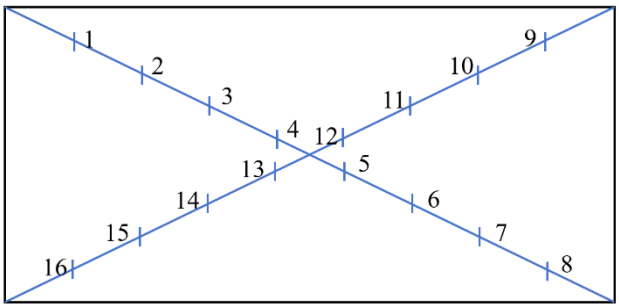

Fig. S1 Sampling point distribution.

2 Total nitrogen, Olsen-P, Olsen-K, organic matter content detected method

2.1 Total nitrogen

(1) Reagent preparation

Mixed catalyst: Mix 100 g of potassium sulfate, 10g of copper sulfate, and 1g of selenium powder ground into powder; Concentrated sulfuric acid: 1.84 $kg \cdot cm^{-3}$ (analytical pure): 1.84 $g \cdot mL^{-1}$; Sodium hydroxide solution (10 $mol \cdot L^{-1}$): Put 200 g of sodium hydroxide into a 500 mL beaker and dissolve it in 250 mL of carbon dioxide free distilled water. After cooling, prepare 500 mL of carbon dioxide free distilled water, mix thoroughly, and store in a plastic bottle; Mixed indicator: Dissolve 0.099 g of bromocresol green and 0.066 methyl red in 100 mL of ethanol free solution; Boric acid indicator solution; Dissolve 20 g of boric acid in 950 mL of hot distilled water, cool, add 20 mL of mixed indicator, mix thoroughly, then add 2–3 drops of sodium hydroxide (0.1 $mol \cdot L^{-1}$) dropwise until it turns reddish purple (pH about 4.5), dilute to 1 L; Sulfuric acid standard bath solution (0.02 $mol \cdot L^{-1}$): First prepare 0.1 $mol \cdot L^{-1}$ sulfuric acid standard solution, calibrate and dilute 5 times. Prepare a 0.1 $mol \cdot L^{-1}$ sulfuric acid standard solution: Dilute 5 mL of concentrated sulfuric acid to a 1 L volumetric flask.

(2) Operation steps

Soil sample digestion: Weigh about 1.00 g of soil sample, place a small paper strip at the bottom of the digestion tube, add 1.1 g of mixed catalyst, inject 4 mL of concentrated sulfuric acid, shake well, cover with a small funnel, and place on the digestion furnace at 400 ℃ for 90 min.

After the digestion furnace stops heating, cool for 30 minutes, remove the digestion tube, clean the still, add 20 mL of sodium hydroxide (10 $mol \cdot L^{-1}$) solution, place the digestion tube on the distillation interface of the nitrogen analyzer, and wash the digestion tube 4–5 times with a small amount of distilled water, 3–5 mL each time. Prepare a marked triangular flask with 5 mL of boric acid indicator liquid inside. Place the triangular flask under the receiving tube of the condenser,

and then start the distillation device for distillation, when the distillate in the triangular flask reaches 40–50 mL, start distilling the next soil sample. Remove the triangular flask and titrate with 0.02 mol·L^{-1} sulfuric acid standard solution until the endpoint is purplish red. Perform 2–3 blank controls simultaneously.

2.2 Olsen-P

Extract soil phosphorus with 0.5 mol·L^{-1} sodium bicarbonate solution. Sodium bicarbonate can inhibit the activity of Ca^{2+} in the solution, allowing certain active calcium phosphate salts to be leached out; at the same time, it can also cause hydrolysis and leaching of active iron phosphate and aluminum salts. The phosphorus in the leaching solution does not cause secondary precipitation; Molybdenum antimony colorimetric method can be used for quantification.

2.3 Olsen-K

About 95% of soil available potassium is exchangeable potassium, while water-soluble potassium only accounts for a very small portion. Therefore, the potassium ions in the soil sample were first extracted using an extraction solution (1 mol·L^{-1} NH_4OAc. In addition, the test solution can be directly determined by flame light without interference, Therefore, the method for measuring soil available potassium in this article is flame photometry.

2.4 Organic matter content

(1) Reagent configuration

Potassium dichromate standard solution (0.8 mol·L^{-1}): 39.2 g of potassium dichromate is dissolved by heating in 400 mL of water, cooled, and then brought to volume in a 1-L volumetric flask. Used for oxidizing soil organic matter at high temperatures. Ferrous sulfate solution (0.2 mol·L^{-1}): dissolve 56.0 g of ferrous sulfate in water, add 15 mL of concentrated sulfuric acid, and make up to 1 L. Used for titrating potassium dichromate; phenanthroline indicator: 1.485 g of phenanthroline and 0.695 g of ferrous sulfate are dissolved in 100 mL of water and stored in a brown bottle as indicators; concentrated sulfuric acid reagent, acidic solution, catalytic effect.

(2) Operation steps

Weigh approximately 0.3 g of 0.149 mm sieved soil sample and place it into a digestion tube. Then accurately add 5 mL of potassium dichromate solution and 5 mL of concentrated sulfuric acid; place the prepared soil sample and the digestion tube of the medicine on the digestion furnace. The temperature and digestion time of the digestion furnace are 150 ℃ and heated for 45 min, respectively. Each test sample needs to be placed in the blank control group without soil sample added; take out the digestion tube and cool it for 4–5 min. Transfer the liquid to a 1.50 mL triangular flask, wash the digestion tube 3–4 times with distilled water, and transfer the washing solution together into the triangular flask. Control the solution volume in the triangular flask to 80 mL; add 3–4 drops of ortho phenanthroline indicator to the specific test solution in the triangular flask; titrate with ferrous sulfate standard solution, with the solution color ranging from orange yellow green brown red, and record the consumption of ferrous sulfate.

(3) Result calculation

$$M_o = 100 \times [(c \times V_1)/V_0 \times (V_0 - V) \times M \times 0.001 \times 1.08 \times 1.724]/m$$

Among them, M_o is soil organic matter mass fraction (%); c is concentration of potassium dichromate standard solution (mol·L^{-1}); V_1 is adding the volume of potassium dichromate standard solution (20 mL); V_0 is volume of ferrous sulfate standard solution used for blank calibration (mL); V is volume of ferrous sulfate standard solution used for titrating soil samples (mL); M is molar mass of (1/4) C (3 g·mol^{-1}); m is actual mass of air-dried soil added (g).