Practical Research on Soil Nutrient Detection Technology Based on Visual Colorimetry

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Abstract

Objective: Research on rapid detection equipment for nutrients in soil to achieve on-site multi-indicator rapid detection of soil. **Method:** Design the hardware of the equipment, including the design of extraction reagents, colorants, and colorimetric strips; And verify the reliability of soil rapid detection equipment. **Result:** By analyzing the detection principles of nutrients in soil, a rapid detection equipment for soil nutrients has been developed. The precision and stability validation was conducted using this equipment and the methods specified in national standards under the same concentration conditions. The results showed that there was no significant difference between the two methods for organic matter, ammonium nitrogen, available phosphorus, and available potassium in soil. The rapid detection equipment for soil nutrients is reliable. **Conclusion:** The rapid soil detection equipment has high detection accuracy and stability, which can meet the requirements of on-site rapid soil detection.

Keywords

Soil, Rapid detection, Hardware design, Nutrient

Research significance

As an important resource of the national economy, the soil is a complex of loose porous material and related natural geographical elements that can grow plants on the land surface. Soil testing and fertilization was proposed by Mitscherich in Germany in the 1930s and completed in the United States by Bolle in the mid-1940s. Bolle first proposed the concepts of soil nutrient availability and crop relative yield and believed that there was a statistical correlation between the test value of soil available nutrients and crop yield or nutrient absorption amount and could establish a mathematical model. Compared with the world average level, the quantity and quality of soil resources in China are severely limited. As an advanced scientific fertilization technology, soil testing and formula fertilization have been carried out in China since 2005, and large-scale soil testing and formula fertilization have been carried out nationwide, which has found out the soil bottom of cultivated land. The fertilization index system of main crops has been preliminarily established. It has realized the double increase in crop yield and farmers' income, promoted the double saving of production cost and resource consumption, accelerated the double optimization of fertilizer structure and fertilizer industry structure, promoted the double improvement of scientific fertilization level and fertilizer utilization rate, and greatly promoted the application of scientific fertilization technology. GB 28735-2012 "Technical Specification for Soil Determination Method and Fertilizer formulation Application", NY/T 1118-2006 "Technical Specification for soil Testing and Fertilizer formulation", NY/T 2700-2015 "Technical Specification for soil testing and Fertilizer application in Grassland alfalfa", and T/GDNB were formed Technical documents such as 98-2022 "Gongtang Soil Testing formula Nutrition Diagnosis and Fertilization Technical Regulations" and DB36/T 1624-2022 "Hilly red soil tea Garden Formula Fertilization Technical Regulations". national soil survey is a soil survey conducted by a professional team to guide the masses for the purpose of comprehensively checking the rational use of soil resources and improving soil. It is a process of conducting soil surveys and mapping step by step from bottom to top, compiling and summarizing soil data, and accepting the results in accordance with unified

investigation procedures nationwide or regionally. Since 1949, China has conducted two nationwide soil surveys and two soil pollution surveys, and the third soil survey will be launched in February 2022. Organic matter, ammonium nitrogen, available phosphorus, and available potassium in soil are the most important soil nutrient indexes. Aiming at soil nutrients, a rapid testing instrument with faster speed, lower cost, and simpler testing equipment has been developed, which is of great significance for farmers to obtain soil quality data in time, understand soil conditions, test soil for formula fertilization, and promote high-quality development of agricultural products. (1) Previous research progress: Soil rapid detection equipment can realize the field rapid detection of soil. Rapid detection methods have been widely studied and applied in soil nutrient detection. There is research on rapid detection methods based on visible near-infrared spectroscopy, atomic absorption spectrophotometer, and inductively coupled plasma atomic emission spectroscopy [1-3], development of conductive detection and online enrichment technology and hyperspectral fast portable instruments [4, 5], improvement of standard detection methods [6-8] and other rapid detection methods [9-17]. (2) Research entry point: Based on the lack of basic knowledge of farmers' detection, a simple visual colorimetric measurement method was established, the professional and complex soil nutrient detection work was left to farmers themselves, and a model of "qualitative detection, farmer self-inspection and quick application" of soil testing and formula fertilization technology was established. (3) Key problem to be solved: To optimize the different extraction liquids, masking agents, color-developing agents, and strong color agents of organic matter, ammonium nitrogen, available phosphorus, and rapidly available potassium in the soil, to provide a scientific basis for the development of rapid detection equipment with low cost and simple operation. Fundamentally solve the problem of one place and one test, and truly realize the formula fertilization of soil testing.

1. Principle and hardware composition of soil nutrient rapid detection

1.1 Experimental principles

1.1.1 Principle of Organic Matter Detection

By using glucose solution as reference material, potassium dichromate solution was used to oxidize soil organic matter. The color of the oxidized solution was directly correlated with organic matter, and the content of organic matter in the soil was directly compared visually.

1.1.2 Detection principle of available phosphorus and ammonium nitrogen

The contents of ammonium nitrogen, available phosphorus, and available potassium in the soil were determined by visual colorimetry after the reaction of ammonium, phosphate, and potassium ions in the extraction solution with Natriolli reagent, acidified ammonium molybdate, and sodium tetraphenyl borate, respectively.

1.2 Checking device hardware components

The hardware of organic matter, ammonium nitrogen, available phosphorus, and rapidly available potassium in soil is shown in the figure below, including ammonium nitrogen A reagent, ammonium nitrogen B reagent, ammonium nitrogen C reagent, and ammonium nitrogen D reagent; Available phosphorus A reagent 5 drops, available phosphorus B reagent 5 drops, available phosphorus C reagent 1 drop; Organic extract, colorimetric card, filter paper, beaker, etc.

Appearance

Figure 1. Rapid detection box for 3 kinds of nutrients in the soil.

2. Study on rapid detection method of soil nutrients

2.1 Sample preparation

The impurities such as plant residues, insect carcasses, and brick stones other than soil were removed from the fresh samples. The soil samples were laid on an air-drying rack or wooden board in a ventilated and light-free room at room

temperature and allowed to air dry naturally. When the soil samples, especially the sticky soil, reached a semi-dry state, the large soil blocks were crushed in time. The soil sample after air drying was crushed with plexiglass and sifted through 2 mm nylon. The remaining sample was further refined through a nylon sieve with a diameter of 0.25mm, thoroughly mixed, bottled, and labeled for later use. Take a clean sample bottle, weigh 2.5g of air-dried soil sample and put it into the sample bottle, weigh 0.5g of soil decolorizer and add it into the sample bottle, measure 50mL of combined extract and add it into the sample bottle, cap the bottle tightly, shake the bottle evenly for 2 minutes, and filter. Absorb 2 mL of filtrate and add it into three colorimetric tubes.

2.2 Ammonium nitrogen test

Take a colorimetric pipe containing 2mL of liquid to be measured and add 6 drops of ammonium nitrogen A reagent, 3 drops of ammonium nitrogen B reagent, 4 drops of ammonium nitrogen C reagent, and 4 drops of ammonium nitrogen D reagent, respectively. Stand for 10min for color development and compare with the standard gradient color value card to obtain the qualitative value of ammonium nitrogen.

2.3 Available phosphorus test

Take A colorimetric pipe containing 2mL of liquid to be measured and add 5 drops of available phosphorus A reagent, 5 drops of available phosphorus B reagent, and 1 drop of available phosphorus C reagent, respectively. Stand for 10 minutes for color development and compare with the standard gradient color value card to obtain the qualitative value of available phosphorus.

2.4 Organic Matter Test

Take a 25 mL colorimetric tube, weigh 0.5 g of air-dried soil sample, and put it into the colorimetric tube, add 10 mL of organic matter extract, shake well, and allow it to react for 20 min, then add pure water to 25 mL of the colorimetric tube, shake well again and leave the upper layer without suspension, then compare with the standard gradient color value card to obtain the qualitative value of organic matter.

2.5 Production of colorimetric cards

According to the principle of ease of use, the content of 3 kinds of nutrients in soil was divided into 5 grades, and the bar colorimetric card was selected as a semi-quantitative comparison of the detection results. The colorimetric cards are shown in Table 1 below:

Table 1. Colorimetric cards of three nutrients in the soil

Item	Content (mg/kg)				
Available phosphorus	<12	12-24	24-48	48-72	>72
Ammonium nitrogen	<30	30-60	60-90	90-120	>120
Organic matter	<5	5-15	15-20	20-25	>25

2.6 Repeatability Verification

Verify the repeatability of the rapid detection method according to the sample pretreatment steps specified in 2.1~2.4. In order to facilitate data statistics, the test results are based on the test results of the spectrophotometer, and the repeatability verification results are shown in Table 2. It can be seen from Table 2 that the precision of the method ranges from 1.87 to 4.04%, indicating that the linearity of the method is good.

Table 2. Method precision (n=7)

Item	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	RSD/%
Ammonium nitrogen (mg/kg)	94.1	95.7	97.2	92.8	95.7	96.2	98.1	1.87%
Rapidly available phosphorus (mg/kg)	35.2	36.8	36.1	34.9	35.6	35	36.2	1.98%
Organic matter (mg/kg)	15.2	16.3	15.8	14.9	15.3	14.5	15.9	4.04%

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2.7 Comparison and verification with laboratory methods

The established method for the rapid detection of three nutrients in soil was combined with NY/T 1849-2010 "Determination of ammonium nitrogen, available Phosphorus and available potassium in acidic soil by combined extraction - colorimetric method" and NY/T 1121.6-2006 "Soil Detection - Part 6: The comparative verification experiment was carried out, and the same sample was sent to three qualified testing institutions respectively for comparative verification. The results are shown in Table 3. As can be seen from Table 3, the consistency between the method and laboratory test data ranges from 90.0 to 103%, meeting the requirements of 90% to 105%.

Table 3. Accuracy evaluation table of ammonium nitrogen results

Item	Institution 1		Institution 2		Institution 3	
Inspection method	NY/T 1849-2010	Quick test	NY/T 1849-2010	Quick test	NY/T 1849-2010	Quick test
High content	120	115	125	113	130	121
Medium content	81.2	79.2	80.1	82.5	85.7	80.1
Low content	41.7	39.7	38.7	39.2	45.8	42.6
Consistency	95.2%~97.5%		90.4%~103%		93.0%~93.5%	
Evaluation result	Meet the requirements of 90%~105%					

Table 4. Accuracy evaluation table of available phosphorus results

Item	Institution 1		Institution 2		Institution 3	
Inspection method	NY/T 1849-2010	Quick test	NY/T 1849-2010	Quick test	NY/T 1849-2010	Quick test
High content	80.7	75.2	85.3	79.8	81.4	74.1
Medium content	35.2	33.1	35.7	32.8	36.2	35.1
Low content	17.1	15.5	17.8	16.1	18	16.7
Consistency	90.6%~94.0%		90.4%~93.6		91~97%	
Evaluation result	Meet the requirements of 90%~105%					

Table 5. Evaluation table for the accuracy of organic matter results

Item	Institution 1		Institution 2		Institution 3	
Inspection method	NY/T1121.6-2006	Quick test	NY/T1121.6-2006	Quick test	NY/T1121.6-2006	Quick test
High content	31.3	29.8	35.7	28.6	31.3	29.8
Medium content	15.6	14.3	15.8	14.9	15.6	14.3
Low content	10.2	9.13	11.5	8.10	10.9	9.03
Consistency	90.0%~95.2%		91.3%~96.5%		90.2%~95.2%	
Evaluation result	Meet the requirements of 90%~105%					

3. Conclusion

Soil testing fertilization originated in the 1930s, through manual intervention fertilization, so as to achieve an economic fertilizer amount suitable for plant growth. Based on the rapid detection method of three nutrients in soil established by the project, the professional and complex soil nutrient detection work is left to the farmers themselves to complete, and the exploration of soil nutrient self-test mode in family farms and the formulation application of quick test results are carried out. The rapid detector has the advantages of low cost, simple testing equipment, and meets the nutrient testing technology required for soil testing and formula fertilization.

Funding

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