Study on Available Nutrients of Soil in Fenlong by a New Farming Method

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Abstract Taking 0 –30 cm, 0 –40 cm, 0 –50 cm, 0 –60 cm of dry land Fenlong and 0 –40 cm paddy field as samples of soil profile with corresponding original soil as the control group, we measured content of organic matter, quick-acting N, quick-acting P and quick-acting K, effective B, Cu, Zn and Mn. Results indicate that available nutrients in soil after Fenlong were higher than original soil. For dry land, the increase of organic matter, quick-acting N, quick-acting P and quick-acting K is 3.02% –35.16%, 6.80% –39.54%, 2.81% –44.46%, and 7.72% –53.71% respectively. There is also increase in effective content of trace element, B, Cu, Zn and Mn. For paddy field, the increase of organic matter, quick-acting N, P and K is 19.64%, 24.02%, 24.27% and 57.78% respectively. Besides, there is also increase in content of trace element, B, Cu, and Zn. On the basis of analysis, we put forward the new theory of crop cultivation " root" theory.

Key words Fenlong, Activated and used, Available nutrients of soil, Increase in content, Root theory

1 Introduction

From the primitive slash and burn cultivation to manual land preparation, animal power land preparation, and tractor land preparation, each time of change of farming method increases soil depth in arable layer and thinning of soil blocks, and crop yield will increase accordingly. However, the present farming method is still plowing and harrowing. How to create new farming method on the basis of this, realize deep plowing and scarification, make available nutrients of soil activated and used, and promote crop growth, is of great significance. Deep plowing of soil can increase scarified soil capacity and soil dressing, increase depth of active soil stratum, promote better growth and development of crop root system and improve crop yield[1-3]. Deep plowing and scarification of soil can accelerate infiltration speed of natural precipitation and manual irrigation, then increase water capacity of soil, keep much water in soil for a long time, improve utilization efficiency of nutrients and drought-resistant capability, and promote high yield of crop[4,5]. Besides, there are many research on influence factors of soil fertility, for example, returning straw to field can provide favorable exogenous nutritious environment[6,7], favorable for increasing content of organic carbon in soil[8], increase water holding capacity of soil[6], and promote increase in content of other nutrients to some degree[9-11]. However, few researches are related to increasing available nutrients of soil through improving land preparation manner. We summed up evolution of farming methods and their effect, to study the influence of changes of farming methods on nutrients of soil. This method is changing the traditional plow and harrow land preparation of dry land farming into vertical Fenlong (meaning smash-ridging) deep plowing and scarifying. The deep plowing and scarifying machine vertically smashes the soil and naturally suspends to form ridges. We call this method " Fenlong cultivation technique for dry land crops". This technique has been experimented in crops, including corn, peanut, soybean, Common Yam Rhizome (*Rhizoma Dioscoreae*), showing developed root system, strong plant and higher performance of yield increase[12-14]. We measured and analyzed the available nutrients of soil through comparing soil after Fenlong operation and the original soil. Finally, we obtained the data of available nutrients for both the Fenlong technique and non Fenlong technique, in the hope of providing reference for scientifically applying and developing " Fenlong cultivation technique for dry land crops".

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2 Materials and methods

2.1 Materials

2.1.1 We adopted vertical Fenlong deep plowing and scarifying machine to smash-ridge (partially rather than globally) according to planting requirements of different crops, forming different planting strips. Fenlong strips and non-Fenlong strips are distributed alternately.

2.1.2 Soil sample.

(i) Dry land in Ningtu Township of Wuming County of Guangxi: Fenlong time: June 3, 2010; sampling time: June 12, 2010. For preceding crop of sugarcane: the Fenlong is 90 cm deep and 30 cm wide (for Common Yam Rhizome); evenly take 0 –30 cm soil on vertical profile of Fenlong strips, and take the 0 –30 cm non-Fenlong original soil closely along the vertical Fenlong profile edge to make comparison; randomly take 3 same kind samples in the same land.

(ii) Dry land in Jinguang Farm of Guangxi State Farms Group: Fenlong time: July 5, 2010; sampling time: July 10, 2010. For preceding crop of ginger: the Fenlong depth is 40 cm, 50 cm and 60 cm respectively; evenly take 0 –40 cm, 0 –50 cm and 0 –60 cm soil on vertical profile of Fenlong strips, and take the 0 –40 cm, 0 –50 cm and 0 –60 cm non-Fenlong original soil closely along the vertical Fenlong profile edge to make comparison; randomly take 3 same kind samples in the same land.

(iii) Paddy field in Xinxu Township in suburb of Nanjing of Guangxi: Fenlong time: May 17, 2010; sampling time: May 17, 2010. For preceding crop of rice: the Fenlong is 40 cm deep and 50 cm wide (for planting grape); evenly take 0 –40 cm soil on vertical profile of Fenlong strips, and take the 0 –40 cm non-Fenlong original soil along the vertical Fenlong profile edge to make comparison; randomly take 3 same kind samples in the same land.

2.2 Measurement method We entrusted Open Laboratory of Agricultural College of Guangxi University and Agricultural Resources and Environment Science of Guangxi Academy of Agricultural Sciences to measure the samples.

2.2.1 Organic matter[15]: weigh 0.05 –0.5 g soil air dried through 0.25 sieve, put the soil into a rigid test tube, add 10.0 ml 4.0 mol/L potassium dichromate-sulphuric acid solution and shake till it becomes evenly; put the test tube into 185 –190 ℃ oil bath pan, keep the temperature of oil bath pan at 170 –180 ℃; when the solution in test tube is boiling, start timing, 5 minutes later, take out the test tube and cool down, later pour all solution in the test tube into a triangular flask, add 3 drops of Phenanthroline, titrate the rest potassium dichromate with $FeSO_4$ standard solution, and calculate the content of organic matter.

2.2.2 Quick-acting N[15]: weigh 2 g soil air dried through 2 mm sieve and 1 g Zn-ferrous sulfate reducing agent, evenly distribute them in outer chamber of diffusion cell, add 2 ml 2% boric acid solution in inner chamber of diffusion cell, and add a drop of nitrogen mixed indicator; evenly apply alkali glue solution at the edge of outer chamber; cover the frosted glass, make the frosted glass bond completely with the cell edge; gently push the frosted glass to make its concave area above the outer chamber, rapidly add 10 ml 1.8 mol/L NaOH solution, immediately cover it with frosted glass tightly, horizontally and gently turn the diffusion cell, to blend NaOH solution and soil uniformly; place it at 40 ℃ thermotank for 24 hours, then use 0.01 mol/L sulfuric acid standard solution to titrate the nitrogen absorbed by boric acid in the inner chamer, finally calculate the content of alkali-hydrolyzable nitrogen.

2.2.3 Quick-acting P (NY/T148 –1990): weigh 2.50 g soil air dried through 1 mm sieve; add 50 ml 25 ℃ extractant (0.5 mol/L $NaHCO_3$, pH = 8.5); at 25 ℃, vibrating extract 30 minutes and immediately filter with phosphate-free filter paper and put it into the dry conical flask; absorb 10.0 ml extract, add 5.0 ml chromogenic agent; slowly shake to make it escape, then add 10.0 ml water and shake uniformly; after placing at room temperature above 15 ℃ for 30 minutes, use spectrophotometer to compare the color, and calculate the content of quick-acting P.

2.2.4 Quick-acting K[12]: weigh 5.00 g soil air dried through 2 mm sieve, put the sample into 200 ml plastic bottle, add 50 ml 1mol/L neutral ammonium acetate solution, tightly fill in the rubber plug, shake at 20 –25 ℃ for 30 minutes, then filter, finally use the filtrate to directly measure the content of K on the flame spectrophotometer.

2.2.5 Effective B (GB12298 –90): weigh 10.0 g soil air dried through 2 mm sieve, put the sample into 250 ml conical flask, add 20.0 ml, connect condenser pipe, heat with slow fire to boiling for 5 minutes, immediately remove heat source, continue to condense through flowing back for 5 minutes, take off the conical flask, add 2 drops of magnesium sulfate solution, and filter after shaking to uniform state; absorb 1.00 ml filtrate and drop into 50 ml evaporating dish, add 4.00 ml Curcumin – oxalic acid solution, and evaporate on thermostatic water bath at 55 ℃ to dry state; when it takes on rosy color, start timing and continue baking for 15 minutes, remove the evaporating dish and cool down to room temperature, add 20.0 ml 95% ethanol, wipe the dish wall with rubber policeman, wait complete dissolution of the content, then filter to plugged container with neutral filter paper, take 95% ethanol as reference solution, measure on the spectrophotometer and calculate content of effective B.

2.2.6 Effective Cu, Zn and Mn[15]: weigh 10 g soil air dried through 2 mm sieve and put the sample into a plastic bottle, add 20 ml DTPA extractant, cover the bottle cap, shake at 180 r/min and 25 ℃ for 2 hours, filter and directly measure with atomic Absorption spectrophotometer, and calculate the content of effective Cu, Zn and Mn.

2.4 Statistical method Data was handled with the aid of Excel and analyzed with SPSS software.

3 Results

3.1 Available nutrients of soil in Fenlong dry land in Ningwu Township of Wuming County

3.1.1 Organic matter and major element quick-acting ingredient content. From Table 1, it can be seen that the organic matter content and quick-acting N, P and K content in smash-ridged soil in dry land are significantly higher than non-smash-ridged soil, with increase of 35.16%, 39.54%, 44.46% and 53.71% respectively.

3.1.2 Trace element quick-acting ingredient content. Table 2 indicates that the difference in effective B between Fenlong and non-Fenlong is not significant, in absolute value; the content in non-smash-ridged soil is slightly higher than Fenlong soil; the effective Cu content in smash-ridged soil is significantly higher than non-smash-ridged soil; the difference in effective Zn content reaches extremely significant level between Fenlong and non-Fenlong.

Table 1 Organic matter and major element quick-acting ingredient content of soil on Fenlong and non-Fenlong in dry land

Nutrients	Fenlong	CK	Increase of Fenlong compared with the control group//%
Organic matter//%	1.23 a	0.91 b	35.16
Quick-acting N//mg/kg	46.16 A	33.08 B	39.54
Quick-acting P//mg/kg	7.96 A	5.51 B	44.46
Quick-acting K//mg/kg	63.93 A	41.59 B	53.71

Table 2 Trace element quick-acting ingredient content of soil on Fenlong and non-Fenlong in dry land

Nutrients	Fenlong	CK	Increase of Fenlong compared with the control group//%
Effective B//mg/kg	0.48 a	0.57 ab	-15.79
Effective Cu//mg/kg	0.55 a	0.37 b	48.65
Effective Zn//mg/kg	0.47 A	0.11 B	327.27

3.2 Available nutrients of soil with different depth of Fenlong in dry land in Jinguang Farm of Guangxi State Farms Group

3.2.1 Organic matter and major element quick-acting ingredient content. From Table 3, it is known that for different Fenlong depth, the organic matter and quick-acting ingredient content are different, and most are higher than the corresponding original soil, and the maximum increasing degree up to 35%.

Table 3 Organic matter and major element available ingredient content of soil on different Fenlong depth of dry land

Treatment	Nutrients	Fenlong	CK	Increase of Fenlong compared with the control group//%
0-40 cm	Organic matter//%	33.04 a	32.07 a	3.02
	Quick-acting N//mg/kg	133 a	105.1 b	26.55
	Quick-acting P//mg/kg	29.3 a	28.5 a	2.81
	Quick-acting K//mg/kg	335 a	311 ab	7.72
0-50 cm	Organic matter//%	29.61 a	25.7 a	15.21
	Quick-acting N//mg/kg	105.6 a	98.3 a	7.43
	Quick-acting P//mg/kg	11.1 a	8.2 b	35.37
	Quick-acting K//mg/kg	130 a	105 b	23.81
0-60 cm	Organic matter//%	25.64 a	25.73 a	-0.35
	Quick-acting N//mg/kg	105.3 a	98.6 a	6.80
	Quick-acting P//mg/kg	11.5 a	9.4 ab	22.34
	Quick-acting K//mg/kg	152.2 a	125.4 b	21.37

Note: the Fenlong depth is calculated from the top of ridge surface: for 0-40 cm, the depth below the ground is 30 cm; for 0-50 cm, the depth above the ground is 38 cm; for 0-60 cm, the depth below the ground is 45 cm. The same below.

3.2.2 Trace element quick-acting ingredient content. Table 4 lists trace element effective ingredient content of different Fenlong depth soil. Except effective Cu in 0-50 cm depth and effective B in 0-60 cm depth, content of other elements in other depths is all higher than non-Fenlong soil.

Table 4 Trace element effective ingredient content of different Fenlong depth soil in dry land

Treatment	Nutrients	Fenlong	CK	Increase of Fenlong compared with the control group//%
0-40 cm	Effective B//mg/kg	2.33 a	1.74 b	33.91
	Effective Mn//mg/kg	0.43 a	0.34 ab	26.47
	Effective Zn//mg/kg	6.42 a	5.51 a	16.52
0-50 cm	Effective B//mg/kg	0.58 a	0.35 ab	65.71
	Effective Mn//mg/kg	0.22 a	0.24 a	-8.33
	Effective Zn//mg/kg	1.67 a	1.08 b	54.63
0-60 cm	Effective B//mg/kg	0.47 a	0.5 a	-6.00
	Effective Mn//mg/kg	0.26 a	0.19 ab	36.84
	Effective Zn//mg/kg	1.72 a	1.55 a	10.97

3.3 Available nutrients of soil in Fenlong paddy field in Xinxu Township of Nanning City

3.3.1 Organic matter and major element quick-acting ingredient content. Table 5 indicates that the difference in organic matter and quick-acting P content between Fenlong paddy field and non-Fenlong paddy field is not significant; the difference in quick-acting N reaches significant between two treatment methods; the difference in quick-acting K content is extremely significant between two treatment methods.

3.3.2 Trace element quick-acting ingredient content. From analysis of trace element effective ingredient content in Fenlong paddy field and non-Fenlong paddy field (Table 4), it is known that the difference in effective B, Cu, and Zn content reaches significant level between Fenlong paddy field and non-Fenlong paddy field.

Table 5 Organic matter and major element quick-acting ingredient content of soil on Fenlong and non-Fenlong in paddy field

Nutrients	Fenlong	CK	Increase of Fenlong compared with the control group//%
Organic matter	1.34 a	1.12 ab	19.64
Quick-acting N	61.54 a	49.62 b	24.02
Quick-acting P	10.19 a	8.20 ab	24.27
Quick-acting K	27.69 A	17.55 B	57.78

Table 6 Trace element available ingredient content of soil on Fenlong and non-Fenlong in paddy field

Nutrients	Fenlong	CK	Increase of Fenlong compared with the control group//%
Effective B//mg/kg	0.86 A	0.27 B	218.52
Effective Cu//mg/kg	2.84 a	2.67 a	6.37
Effective Zn//mg/kg	0.87 a	0.50 b	74.00

4 Discussion

4.1 Influence of Fenlong on changes of soil and its environment In the course of Fenlong, soil and its environment may have following changes.

(i) High-speed rotating vertical spiral drill bit cuts the soil, and the soil structure will be broken partially or wholly.

(ii) During the rotating and grinding of the vertical spiral drill bit, the soil in deep level that contains much water is lifted upward, leading to mutual permeation of water between upper and lower soil and realizing uniform distribution of soil water.

(iii) When high-speed rotating drill pit brings along exchange of upper and lower soil water, it will bring air into soil and fill the soil porosity with air, so Fenlong soil is abundant with air.

(iv) High-speed mechanical rotation will bring about temperature rise effect and lift the temperature of Fenlong soil in the twinkling of an eye.

(v) Under the influence of sufficient air, suitable water content and temperature rise, the activity of some soil enzymes will be activated.

Influenced by the above factors, some chemical reactions may happen in the soil, thus activating and increasing effective nutrients of the soil.

4.2 Influence of Fenlong on available nutrients of soil The organic matter is an important indicator of soil fertility[16]. It can provide direct nutrient for crops and also can improve physical traits of soil[17]. Soil water is the carrier for transporting water soluble elements in soil and also the medium ensuring normal soil reaction[18]. In certain temperature range, temperature rise will promote decomposition of organic matter in the soil[19-21]. Activity of soil microorganism can degrade residual bodies of plants and animals within the soil and increase organic matter content[17]. During the Fenlong, temperature rise, uniform water distribution and sufficient air intensify activity of soil microorganism, and consequently promote increase in organic matter content in the soil.

Researches have shown that nitrogen element is subject to leaching. In the growth period of some crops, unused nitrogen element will be permeated to the bottom level of plowing[22], and some form of nitrogen nutrient may be absorbed by colloid in the soil, leading to failure to be used by crops[23]. Study of Wang Xiqing et al indicates that in certain range, NH +4 – N nitrification rate rises with increase of soil water content[24]. In the course of Fenlong, high-speed rotating drill pit will break the soil structure and smash the bottom level of plowing, lift lower soil (about 20%) up to cultivation level. Through Fenlong, it also can uniformly distribute soil water into scarified soil layer. Changes of soil environment after Fenlong will accelerate release of effective nitrogen, which may be the reason for increase of quick-acting N content in the Fenlong soil.

Phosphorus fertilizer is easily fixed and difficultly absorbed by crops[25, 26]. However, desorption of phosphorus element is influenced by many factors, including temperature and pH value[27]. With the temperature rise, phosphorus element released by soil gradually increases[28]; with rise of pH value, the absorbed phosphorus element also increases, in other words, drop of soil pH value can increase desorption of phosphorus element. Potash fertilizer is easily soluble in water. Once applied into soil, the K ion is easily replaced and absorbed by other ions[30]. The factors of soil pH value, temperature and water content will influence K + absorption and desorption[31]. Soil temperature rises, the selectivity of soil absorbing K will fall and concentration of solution K will increase[32, 33]. Drop of soil pH value is favorable for desorption of K ion[34, 35]. Due to mechanical friction in the course of Fenlong and improvement of soil environment after Fenlong (such as rise of soil temperature, suitable water content, increase of porosity, and sufficient air), active substances in the soil release phosphorus and potash elements fixed in the soil again, finally increasing the quick-acting P and quick-acting K content in the soil.

Factors influencing effect of trace elements in soil mainly include: soil pH value, oxidation-reduction state and organic matter content[36]. A lot of researches have proved that in acid soil condition, rise in solubility of Fe, B, Mn, Cu and Zn will lead to rise of effect[37, 38]. This study was carried out in acid soil. The deep Fenlong lifts soil at part of bottom level of plowing, reduces pH value of the entire active soil layer, finally increases the effect of trace elements, including B, Zn, Cu and Mn.

4.3 Relation between Fenlong technique and root system in seedling stage and the crop yield For corn, peanut, soybean, sugarcane and (drought) rice planted in the soil by the Fenlong technique, seedling stage of each crop shows extremely developed root system. The root length and quantity of fibrous root are 20 – 40% higher than that by the traditional tractor land preparation method; the actual yield of corn is 10 – 25% more than that obtained by traditional method. This also indirectly indicates that Fenlong can activate soil nutrients, increase content of available nutrients, and bring about better root system growth at the early stage of crop growth and final yield increase.

4.4 Influence of Fenlong on future crop cultivation In sum, Fenlong changes physical and chemical traits of soil, which is favorable for crop growth, especially for growth and development of root system[39], while the situation of crop root system determines plant traits and economic yield. Therefore, we put forward a new concept – "root" theory, namely, crop cultivation should be based on cultivating good root system.

5 Conclusions

Fenlong of dry land and paddy field can activate soil nutrients, greatly increase available nutrient content, so it can be used as a new approach for activating soil nutrients and reducing pressure of manual application of fertilizer.

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done in order to verify under which conditions, assumptions, models, function forms, parameterizations, regional partitions *etc.*, some results hold or not. For instance we can relax the superaditivity and positive externality assumption used in Carraro, Eyckmans and Finus (2006) to see if OPTS is still helpful. Or we allow the possibility of multiple coalitions formation, add endogenous or exogenous shocks in the game, try a repeated or dynamic game model, consider the asymmetric information and so forth. Moreover we can inject the political negotiation part into the model since the IEA formation is intrinsically a political-economic procedure but rare literatures have done that. Harstad (2008) is a recent attempt in which it explores the transfer in the context with strategic delegation of negotiation, and finds that "side payments are bad if the heterogeneity is small while the uncertainty and the typical value of the project are large". Nevertheless saying is always easier than doing, in the field of side payment economists have a long way to go.

Note: ① (i) In many articles, emission abatement cost $C_i(\cdot)$ only depends on the abatement effort of the individual country *i* who manages to reduce emission. However, due to the externalities, sometimes abatement cost will also depend on other countries' abatement (for example, Germany's air pollution damages the health of French workers and hence reduces the productivity in France, the lowered productivity makes the emission reduction cost in France higher).

(ii) Alternatively, we can form the welfare function with respect to the quantity of emission:

$$U_i = B_i - D_i = B_i(x_1, x_2, \cdots, x_i, \cdots, x_n) - D_i(x_1, x_2, \cdots, x_i, \cdots, x_n) \quad (1')$$

where $B_i(\cdot)$ is the gain by emitting pollutant, $D_i(\cdot)$ is the damage from pollution (mainly subjectively evaluated), and x_i country *i*'s emission. It is not difficult to see the equivalence of these two formations. See Ioannidis, Papandreou and Sartzetakis (2000).

(iii) It is also feasible to use the way of minimizing the total cost function instead of maximizing the welfare function. Total Cost is the sum of emission abatement cost and damage cost:

$$TC_i = C_i + D_i = C_i(q_1, q_2, \cdots, q_i, \cdots, q_n) + D_i(q_1, q_2, \cdots, q_i, \cdots, q_n) \quad (1'')$$

or

$$TC_i = C_i + D_i = C_i(x_1, x_2, \cdots, x_i, \cdots, x_n) + D_i(x_1, x_2, \cdots, x_i, \cdots, x_n) \quad (1''')$$

Chander and Tulkens (1994) use this manner. Definitely a linear transformation to $C_i(\cdot) + D_i(\cdot)$ would give $B_i(\cdot) - C_i(\cdot)$ or $B_i(\cdot) - D_i(\cdot)$ respectively in our equation (1) and (1′).

② Carraro and Siniscalco (1993) give an initially systematic investigation for types of transfers. Carraro, Eyckmans and Finus (2006) classify them into such approachable groups that I generally follow them.

③ In some papers, the argument in the weight is B'_i rather than D'_i where B'_i is the marginal benefit of pollution abatement. This alternative formation in fact makes no difference, by the same reason as in footnote ① (ii).

④ Unexpectedly in Carraro, Eyckmans and Finus (2006) the profitability condition is ignored. I cannot find an interpretation to not add it here.

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