STUDY ON SOIL IMPROVEMENT FOR RECLAIMED SUBSIDED LAND WITH FLY ASH AND ORGANIC FERTILIZER[1]

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Abstract. Reclaimed land usually has some problems such as poor soil structure and nutrients shortage. The man-made improvement treatments could accelerate soil development of reclaimed soil and increase soil productivity. This study was conducted to determine the effectiveness of soil improvement with fly ash and organic fertilizer for reclaimed subsided land. A 0.23 ha of experimental site was chosen in Jiawang coal mining area, Jiangsu province, and 6 treatments were used in the design with 3 types of materials such as 1% fly ash, 5% fly ash and poultry litter. The results showed that the application of fly ash could improve the reclaimed soil, but the amount of the fly ash should be more than 1%. The treatment of 1% fly ash had the lowest yield of soybeans, even lower that of the reference plot. As fly ash has fewer nutrients, some organic fertilizers are needed for higher yield. The treatment with 5% fly ash with poultry litter had the highest yield of soybeans. All the treatments of soil amendments were lower or equal to the concentrations of metal elements found for the control plot. The addition of organic fertilizer (D, E, F treatments) resulted significant decreases in the concentrations of Zn and Cu in the soybeans while the addition of 5% fly ash had only a slight decrease of the concentration of Zn and Cu in the beans. The pH and available nutrient contents of soils after harvest of the soybean were not affected by the application of fly ash.

Key words: reclaimed soil, soil improvement, fly ash, subsidence land, coal mine

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Introduction

Coal is the most attractive energy resource in China, accounting for approximately 75% of consumption. Underground mines in China account for more than 96% of coal output. With the extraction of coal from underground, the severe land subsidence often results, which always causes huge losses of cultivatable lands. According to recent statistics, the area of subsiding and subsided land from coal mining totals more than 400,000 hectares with an increase of 22,000 hectares each year (Hu and Atkinson 1998). It is well known that China has a very large population and the loss of cultivatable land is very serious problem. The mean of cultivatable and permanent farmland per person in China only equals about one-third of the average value for that of the world. This situation makes the reclamation of subsided land become an urgent task for our Country.

Most of coal is mined for producing electrical power. In China, 83.7% of electrical power is from coal-fire power stations (1999 national statistic data from the Internet). Thus a large amount of fly ash is produced by these power stations, which disposal also impacts a lot of farmlands resulting in additional serious environmental problems. Many studies have shown that using fly ash as soil amendment can improve physical and chemical characteristics of soils and increase the crop yields. Reclaimed soil usually has poor quality with low yields. Applying fly ash during the land reclamation might be beneficial to soil quality and crop growth. However, use of fly ash as a soil amendment must take into account the properties of the fly ash and soils to avoid any adverse impacts of this treatment on plants and environment. This study was undertaken to find out the effects of fly ash applications on reclaimed soils and for the reclamation of subsided land.

Materials and methods

A field experiment was conducted in Jiangsu Province, middle China, warm temperature zone. The minimum temperature is 0.7℃ in winter, and the maximum temperature is 37℃ in summer. The soil was about 40 cm in thickness and classified as Shajiang Black soil, which has high clay content and has ginger-shape stones in bottom layer. The soil bulk density is 1.46Mg/kg, pH 7.9, organic matter 1.27%, and the EC (1:1) of 0.86dS/m. The soils were reclaimed in early 2002 by the method called “strip by layers and replace layers in serial positions (a special order)" with digging machines, which produced to a soil medium similar to the original soil. The experimental design was completely randomized blocks with six treatments and each one replicated three times. Theses treatments were:

Plot A: control (reference) plot, reclaimed soil, no fly ash

Plot B, 1% fly ash (30ton/ha), no organic fertilizer

Plot C, 5% fly ash (150ton/ha), no organic fertilizer

Plot D, organic fertilizer

Plot E, 1% fly ash plus organic fertilizer

Plot F, 5% fly ash plus organic fertilizer

Each of experiment plot was 6 by 11m with a corridor 2m between them. Fly ash used in the experiment was procured from the Jiawang power plant and was applied before the soybeans were seeded. The soil was ploughed and fly ash was incorporated in a depth of about 20cm. Organic fertilizers were applied at the same time. Plant seeding was done on May 19th, 2002 in rows of 0.35m and 0.18cm within the rows. Soybean harvesting was done in October. Table 1 gives the original materials characteristics before planting.

Table1 Some physico-chemical characteristics of reclaimed soils, fly ash and organic fertilizer.

Item	Original Soil	Fly Ash	Organic Fertilizer
pH	7.94	7.85	6.97
EC (dS/cm)	0.86	0.74	-----
Ca (%)	3.20	0.23	3.36
Mg (%)	0.93	0.34	1.74
Fe (mg/kg)	15430.00 (6.96)*	8800.00	11242.00
Mn (mg/kg)	864.00 (4.96)	138.00	968.50
Zn (mg/kg)	70.10 (034)	63.60	227.50
Cu (mg/kg)	31.20 (0.88)	138.00	169.00
Ni (mg/kg)	40.40 (0.12)	36.00	25.20
Cr (mg/kg)	80.10	63.50	38.60

*The numbers in brackets means available concentration extracted by DTPA-ICP

Plant was sampled at every five rows and five plants per row. Yield, height, leave area, leave age, legumes and hundred beans weight were determined at different periods. The harvested plant materials were separated into root, beans and stem (aboveground parts) and washed with distilled water, dried at 70℃ then passed through 1mm sieve and subsequently analyzed. They were analyzed for Ca, Mg, Zn, Fe, Mn, Ni, Cu, Cr by ICP. These elements were chosen by means of a preliminary measurement for elements concentrations in fly ash, where these eight elements show high concentration.

After harvesting the soybean plants, nine surface soil samples (0-20cm) were collected randomly from each plot to make a composite sample. The samples were air-dried and ground to pass through a 1mm sieve. Some soil properties were analyzed: pH in a water:soil suspension 2.5:1; electrical conductivity in a water:soil suspension 5:1; total concentration of the above mentioned elements were digested by HNO_3 + HF, available concentration of the metals Fe, Mn, Cu, Zn, Ni extracted by DTPA, then using ICP (Bao 2000, Baker and Amcher 1982). The data were statistically analyzed by Duncan's multiple range test to detect significant differences among the treatments. Data on plant growth were analyzed by principle component analysis to find the reason of increasing production.

Results and Discussions

Effects of fly ash application on soil pH, EC and bulk density

The soil pH, EC and bulk density were not significant different among the various treatments. The original soil pH (7.9-8.0) and fly ash pH (7.85) were higher than soybean's most desirable growing range 6.8-7.5. But there were no changes in soil pH with the addition of fly ash (see Table 2). Moreover, the inherent buffering power of clay soils would also resist the small changes in pH. While the addition of organic fertilizer with relatively low pH (6.97) decreased the soil pH slightly.

Table 2. Effect of Soil Amendments on pH, EC and Bulk Density Values

Item	Original Soil	Reclaimed Soil Treatments					
		A	B	C	D	E	F
pH	7.94	7.98	7.94	7.94	7.92	7.90	7.91
ED (dS/m)	0.26	0.23	0.23	0.24	0.24	0.26	0.28
Bulk Density (g/cm^3)	1.32	0.38	1.30	1.32	1.29	1.38	1.32

EC increased following fly ash application. The value of EC reached 0.28 dS/m at the highest rate of fly ash with the organic fertilizer application. The increase in EC was caused by the water soluble salt contents in fly ash, e.g. Ca and Mg, which is in agreement with previous findings (Matsi and Keramidas, 1999). This value had strong positive correlation with the soybean yield (0.72), height (0.61) and leave area (0.72). Therefore, this fly ash rate was not detrimental to the soybean, on the contrary, it promoted the plant growth by providing soluble nutrients.

The bulk density had no trend among treatments, because the fly ash application amount was too small. However, the bulk density had some correlation with plant nutrient uptake, which will be described in the following part.

Effect of fly ash application on soybean growth

The soybean yield and biomass are listed in table 3. The results of soybean yield in different treatments were F>D>E>C>A>B. Highest yield and biomass were obtained in Treatment F with 5% fly ash application and organic fertilizer, the relative increase being 27.3% and 30.0% than control plot respectively. Treatment B with 1% fly ash had the lowest yield and biomass. The significant increases of yield and biomass both happened in the treatment of fly ash plus organic fertilizer. The addition of 1% fly ash tended to decrease the soybean yield and biomass, which shows that we should apply more than 1% fly ash if we use fly ash as amendments. Increased yields might be the result of pH and soil nutrient improvement.

Table3. Effect of Fly Ash and Organic Fertilizer Treatments on Soybean Yield and Biomass

Kg/hm^2	Reclaimed Soil Treatments

	A	B	C	D	E	F
Yield	2899	2836	3006	3376	3357	3690
Biomass	5082	5019	5256	5913	6149	6590

The maximum height was also obtained in Treatment F (see Table 4). The differences between treatments with organic fertilizer (D, E, F) and without organic fertilizer (A, B, C) were very pronounced. Leaf age and leaf area had a similar trend. A better plant development and greater enhancement happened on the reclaimed soils amended by fly ash supplement with organic fertilizer.

Other growth parameters including weight per hundred beans, pods per plant and seeds per pod were compared in Table 5. The data indicated that organic fertilizer supplement increased the weight per hundred beans, seed pods per plant.

Table 4. The effect of fly ash on soybean height, leaf age and leaf area

	------ Height (cm) ------			--- Leaf age- ----		Leaf area (cm^2)
	6-19	7-2	Harvest time	6-19	7-2	
Treatment						
A	22.4	36.3	39.3	3.2	5.5	60.9
B	25.4	41.7	42.3	3.5	6.0	79.0
C	25.2	42.8	43.7	3.6	5.9	79.2
D	28.1	50.1	50.3	3.7	6.8	95.1
E	26.8	47.5	50.0	3.8	6.8	101.0
F	28.5	51.3	52.3	3.8	7.1	101.1

Table 5. Effect of fly ash on some growth parameters

Item	--------- Reclaimed Soil Treatments ------------					
	A	B	C	D	E	F
Weight per hundred beans (g)	21.17	21.62	20.91	22.06	22.72	22.00
Seed pods per plant	45.7	45.3	45.4	49.2	49.3	48.0
Empty pods per plant	2.2	2.5	3.0	2.9	2.3	2.8
Seeds per pod	1.7	1.7	1.8	1.8	1.7	1.7

Contents of metal elements in beans

Based on the above-study, we found that soil amendments are needed for improving crop yields. But the key is to determine if the crop contains some hazard elements, which might be harmful for human's health. Thus some metal elements were analyzed in soybean's stem and beans (see Table 6 and Table 7). The results showed that there was a similar trend among the measured 8 elements (see Figure 1), i.e., the treatments of soil amendments had lower or equal to the concentrations of metal elements than that of control plot. It means that soil amendments did not increase the concentrations of potentially harmful metal elements. Only the contents of Cu and Cr were close to the national safety food standard (Cu 20mg/kg, Cr, 1mg/mg), but they still less than that of the Control plot. It might be the soil background has a higher Cr content. Most of the contents of metal elements in soybean stems had no significant difference among different treatments. But the addition of organic fertilizer (D, E, F treatments) resulted significant decrease of the concentration of Zn and Cu in beans while the addition of 5% fly ash also had slight decrease of the concentration of Zn and Cu in beans. All soil amendment treatments had lower contents of Cu than that of control plot. Thus, the addition of fly ash could decrease the concentration of Cu in beans.

Table 6 Concentrations of metal elements in soybean's stem

Treatment	-------%-------		------------------------------- mg/kg -------------------------------					
	Ca	Mg	Fe	Mn	Zn	Ni	Cu	Cr
A	1.45 a*	0.37 a	96.93 ab	26.17 a	13.13 a	0.56 a	11.12 a	1.40 a
B	1.30 ab	0.36 a	87.47 ab	21.60 ab	14.27 a	0.53 a	8.30 a	1.24 a
C	1.19 ab	0.34 a	72.67 b	18.53 b	10.31 a	0.39 a	8.18 a	1.14 a
D	1.05 b	0.30 a	69.77 b	17.83 b	7.79 a	0.34 a	7.09 a	1.12 a
E	1.33 ab	0.36 a	94.90 a	26.83 a	13.68 a	0.62 a	10.95 a	1.39 a
F	1.22 ab	0.34 a	72.67 b	20.77 ab	9.32 a	0.44 a	8.07 a	1.02 a

*means followed by the same letter are not statistically different at $p \leq 0.05$, using Duncan's multiple range test.

Table 7. Contents of metal elements in beans

Treatment	-------%-------		------------------------------- mg/kg---					
	Ca	Mg	Fe	Mn	Zn	Ni	Cu	Cr
A	0.39 a*	0.20 a	49.93 b	34.23 a	58.60 a	0.97 a	19.77 a	0.95 a
B	0.40 a	0.19 a	53.73 a	34.17 a	58.60 a	0.82 a	18.60 ab	1.04 a
C	0.39 a	0.19 a	55.67 a	31.47 a	54.93 ab	0.96 a	18.47 ab	0.95 a
D	0.37 a	0.20 a	55.17 a	33.90 a	50.13 b	1.00 a	17.27 b	1.00 a
E	0.38 a	0.21 a	60.73 a	36.27 a	50.87 b	1.05 a	17.20 b	1.01 a
F	0.38 a	0.20 a	57.40 a	32.47 a	48.53 b	1.02 a	17.17 b	1.04 a

*means followed by the same letter are not statistically different at $p \leq 0.05$, using Duncan's multiple range test.

Conclusions

(1) Soil improvements of reclaimed land are needed for higher production. The order results of soybean yield for the different treatments were F>D>E>C>A>B. The yield increased with fly ash application and organic fertilizers 5% fly ash application plus organic fertilizer had the highest yields.

(2) The application of fly ash had no obvious effect on soil pH and bulk density. Thus alkaline fly ash could also be used to ameliorate alkaline reclaimed soil. But 1%fly ash resulted the lowest yield, therefore, more than 1% fly ash was needed for improvement of crop yield.

(3) All the treatments to the soil had either lower or equal concentrations of metal elements than that of control plot. The addition of organic fertilizer (D, E, F treatments) resulted significant decreases of the concentration of Zn and Cu in soybeans while the addition of 5% fly ash also had slight decrease of the concentration of Zn and Cu in soybeans. Only the contents of Cu and Cr were close to the national safety food standard (Cu 20mg/kg, Cr, 1mg/mg). The addition of fly ash could decrease the concentration of Cu in beans.

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