Remediation of Desertificated Land with the Cola Ash -In the Case of Inner Mongolia of China-

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Remediation of Desertificated Land with the Coal Ash -- In the Case of Inner Mongolia of China --

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Abstract - The natural cultivation experiments and pot planting experiments were performed using desertificated soils of China and coal ashes. The microbes multiplied on and in coal ash, and the plants developed the roots in coal ash more than the plants in pure soils. The addition of coal ash is expected to be very effectual and sustainable way for afforestation in desertificated lands.

I. Pourposes

The desertification is one of the most serious environmental problems at present in the earth. The desertification has already brought about the land deterioration in the area of $3.6\times10^7 km^2$ (25% of the whole ground on the earth) and it affects awfully flora, fauna and the 1/6 people of the world. Most desertification derives from the climate change and human. In the case of China, 27% of total land area has already desertificated, especially in north (Inner Mongolia) and west (Xinjang) parts (Fig.1). In order to prevent the desertification and to rehabilitate the land production capacity, many scientists have carried out the studies from the various viewpoints, namely historical, geographical, pedological and meteorological aspects[1]. Few investigations, however, focused on the soil microbes in desertificated land.

China is also suffering from the large amount of coal ash (residue after combustion), which causes the problems both in the environment and in public health. The coal ash is classified in two types; one is clinker ash (porous structure), and the other is fly ash (spherical and fine particle). The coal ash has utilized primarily in industry and in recent years it has begun to be used as soil improvement materials[2]. This agricultural usage gets advanced rapidly. Few studies, however, has carried out about forestry utilization so far. If the coal ash is available for afforestation in desertificated land, it seemed to be very effective method, because two problems, namely desertification and coal ash, may be solved at the same time. For this purpose, it is necessary to reveal the microbial properties of desertificated soil and interaction among coal ash, plant and microbes.

The purposes of this study are set as following four points; (1) to elucidate the properties of desertificated soils from mineral, chemical and microbial viewpoints, (2) to reveal the mineralogical and microbial changes in soils after afforestation in desertificated land by field investigation, (3) to investigate of the microbial properties through the natural cultivation experiment and pot planting experiment utilizing the desertificated soils mixed by coal ash, and (4) to consider about the remediation of desertification by means of coal ash addition from microbial viewpoint.

II. Methods and Results

The field investigation was carried out in Baotou, Inner Mongolia. The samples of coal ash, soils of afforestation plan areas (now in desertification), reservoir sediments, and the Yellow River sediments were collected there. Mineralogical and chemical analyses showed that the coal ash consists of mullite, quartz and iron oxides with amorphous materials, rich in Si and Al. The SEM image of coal ash showed the mixture of clinker ash and fly ash (Fig.2). The soils of afforestation areas and reservoir sediments consist of quartz, feldspars, calcite and halite, rich in Si, Ca and Fe. In addition, the Yellow River sediments consist of quartz and clay minerals, rich in Si, Ca, Fe and Al.

The natural cultivation experiment was performed using soils and coal ashes. The microbes multiplied more in containers using with soils added coal ash than in those without coal ash. The microscopic observation revealed that the numerous microbes (bacteria and fungi) increased on the surface and inside of coal ash (Fig. 3). The changing tendencies of pH and EC of solutions in containers were measured during 10 days aging. The transformation range of pH and EC were smaller in containers with additional coal ash. Accordingly, it is suggested that the coal ash provided the microbes with living site, namely "micro-habitat", promoted growth of them, and kept the equilibrium in pH and EC.

The pot planting experiments were performed. Poplar,

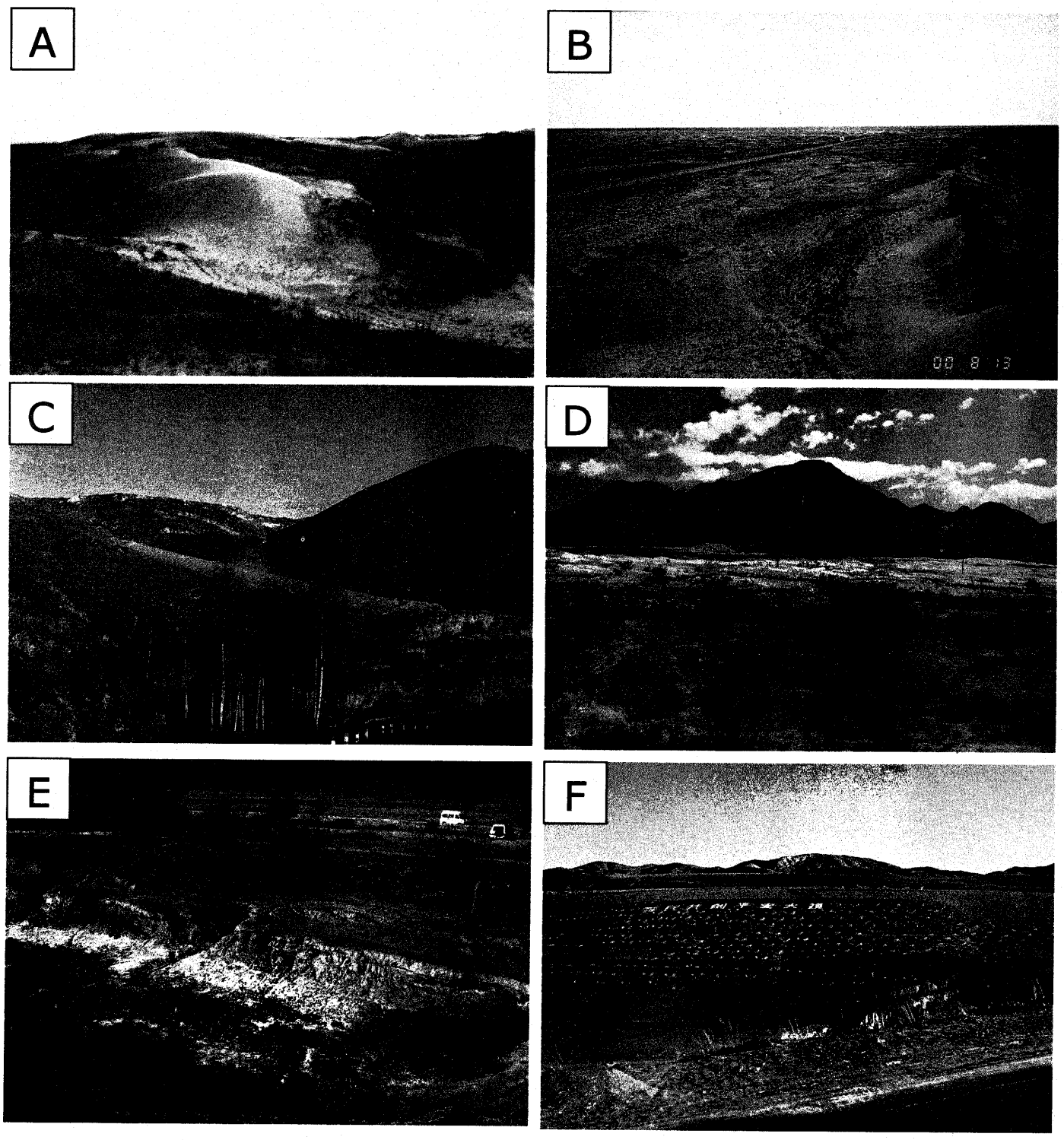

Fig. 1 Characteristic phenomena of desertificated lands in northern China. (A) "Tami-Chaga" area, meaning the "death" in the Chinese with many moving dunes. (B) Mau Us Sandy Land, one of the most serious desertificating areas in China. (C) Inchang Mountains, serious desertificated area after the deforestation about 30 years ago. (D) Ulan Buh Desert, expanding every year very quickly. (E) The dried up river with salinization on the outskirts of Baotou, Inner Mongolia. (F) Many holes for planting can be seen in the desertificated fields but it is hard to regain the green land.

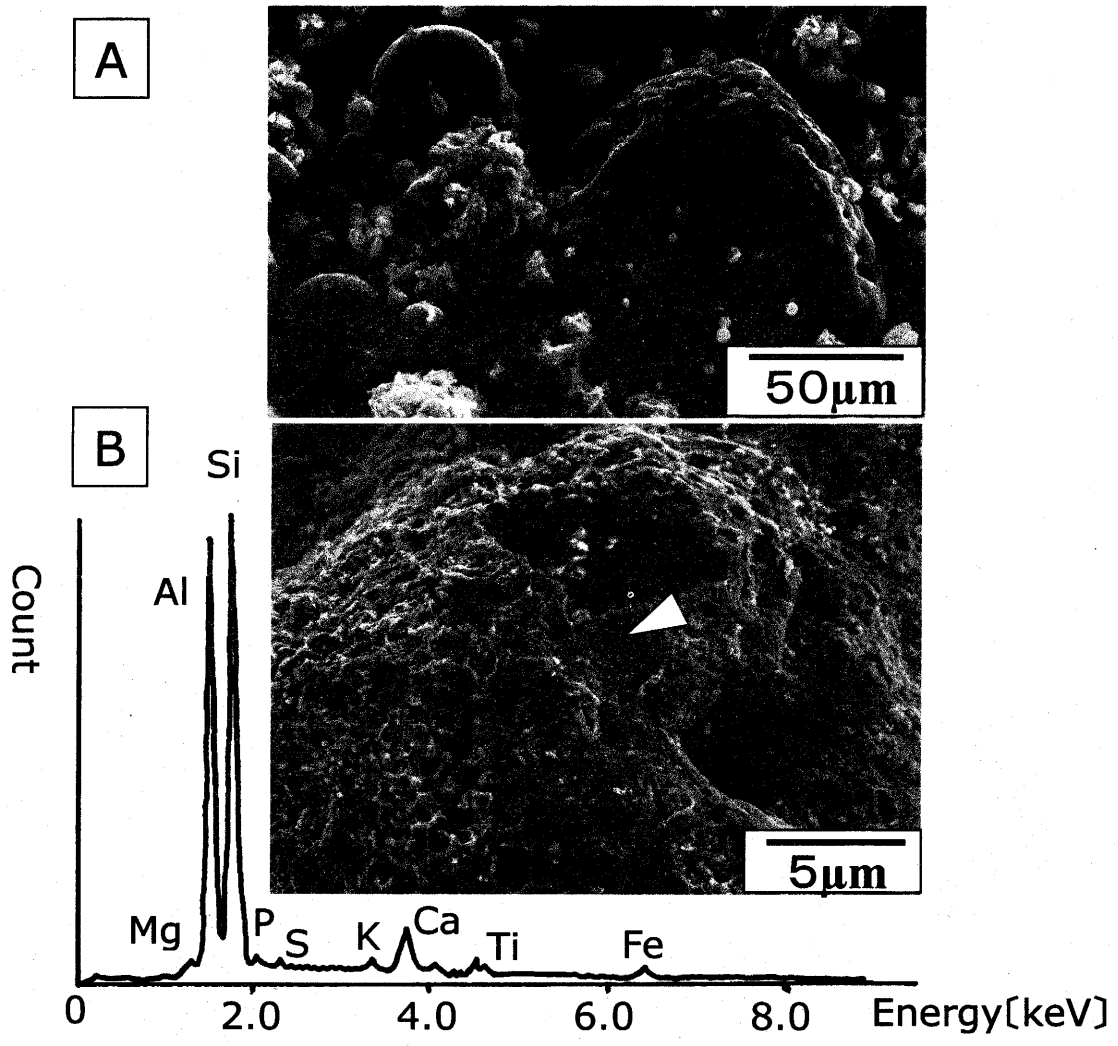

Fig. 2. SEM micrographs of coal ash collected from Coal ash pond 1 of Baotou, Inner Mongolia.
(A) The coal ash is composed of spherical particles (thin arrows in micrograph: **fly ash**) and porous particles (thick arrow in micrograph:**clinker ash**).
(B) The enlarged image of clinker ash showing peaks of Si and Al with traces of Ca, Fe, Mg, K, P and Ti (analytical point: triangular arrow in B).

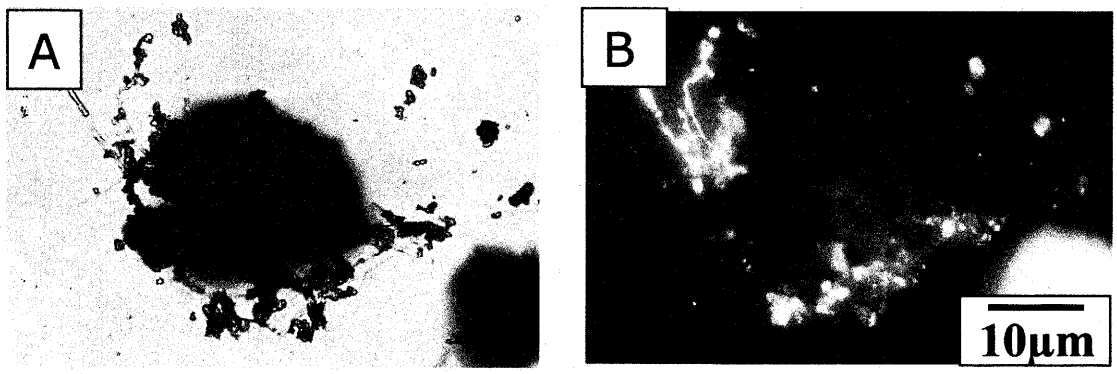

Fig. 3. Optical and fluorescence micrographs of the biofilm formed on the slide glass in natural cultivation experiment utilizing Coal ash-2 of Baotou.
(A) Cocci bacteria and fungi adhered to coal ash particles.
(B) DAPI stained sample indicating that cocci bacteria and fungi tangle with coal ash particles. Cocci bacteria cling to the surface and exist also inside of particles.

Japanese oak, azalea and sasanqua were planted in pots that were filled with four kinds of soils (sand, soils of Baotou, Akadama-soil and Kanuma-soil) added coal ashes (clinker ash, fly ash and Chinese ash) at various mixing rates. The plants in pure clinker ash (100%) and ones in soils mixed with clinker ash survived more and grew up better in height. The plants brought up with clinker ash more leaves, more root hairs and better-grown root than the plants in pure soils (Fig.4-A and B). In media cultivation experiment, the microbes increased more in pots of pure clinker ash and in pots of soils with coal ash, in comparison with the microbes in pots of pure soils (Fig.4-C and D). Furthermore, the addition of coal ash increased K and P in leaves, in spite of low amount of K and P in coal ash itself. The plants in coal ash developed the roots; the microscopic observation revealed that the roots with abundant root hairs reached out to grains of clinker ash and that the roots were covered with the mycorrhizas.

III. Discussion

From these results, it is suggest that the clinker ash can reserve the water well because of its porous structure, and provide the microbes (particularly the bacteria and fungi) with water and living sites (Fig. 5). The microbes multiplied on and in clinker ash and dissolved the elements (P and K) from minerals by bio-weathering[3][4]. Furthermore, since the hyphae supplied the nutrients to plant roots the better, the plants grew up the more clinker ash were added in soils[5]. On the other hands, the porous structured clinker ash would be effective for the ventilation and gas change, especially in Loess (fine clays of yellow colored, which is popular soil in desertificated lands in Chine and shows very tight structure.)

From the above-mentioned results, the addition of coal ash (especially clinker ash) is expected to be very effectual and sustainable way for afforestation in desertificated lands.

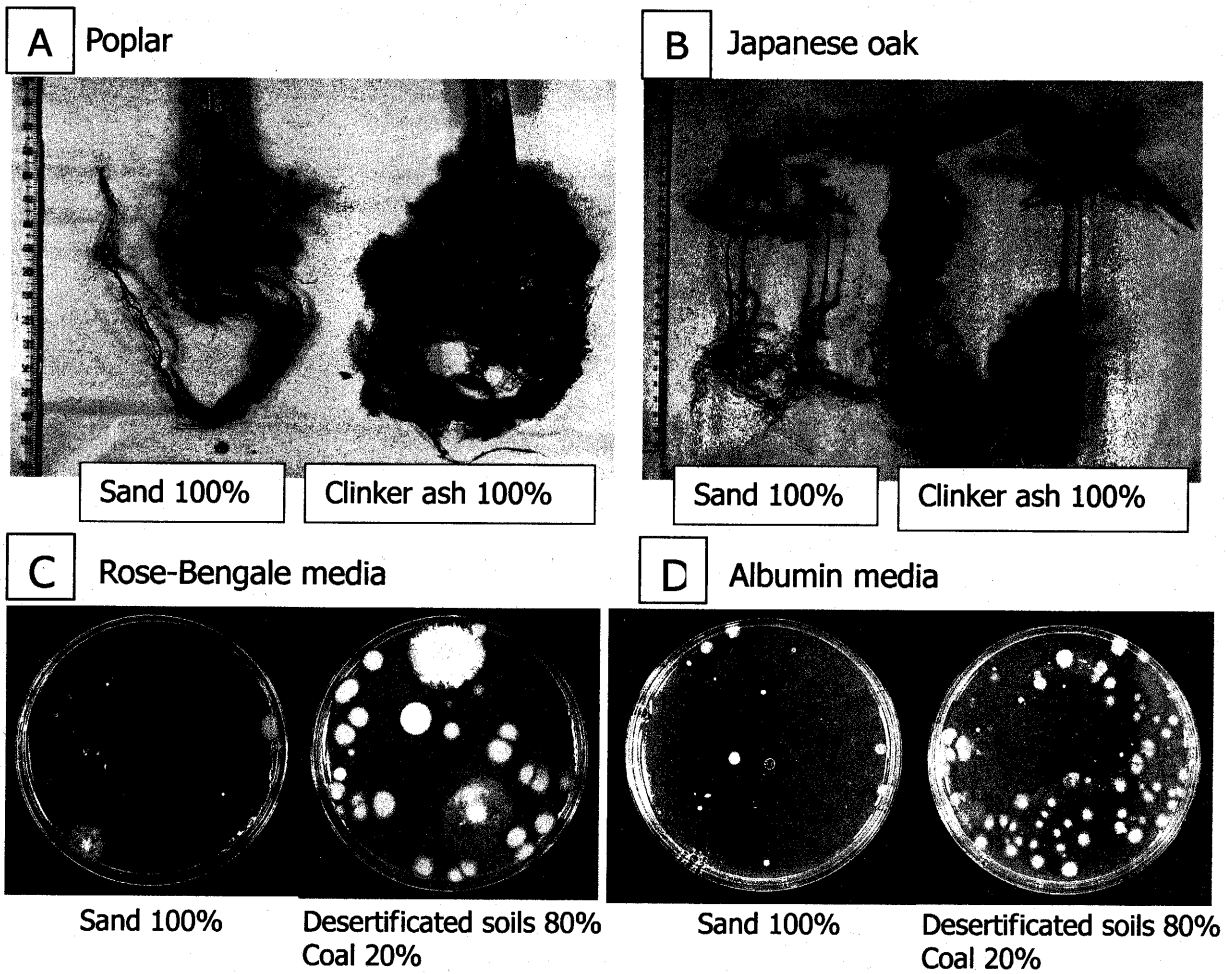

Fig. 4. Comparison of roots between sand 100% and clinker ash 100% in pot planting experiments.
Photographs were taken in October 2001.
(A) Poplars planted in April 2001. (left) sand 100%, (right) clinker ash 100%.
(B) Sowed pots with Japanese oaks in September 2000. (left) sand 100%, (right) clinker ash 100%.
Both plants in clinker ash develop the roots more than the plants in pure sand.
The poplars and Japanese oaks twine the roots around the clinker ash grains.
(C)(D)Cultivation results in media of soil-microbes with poplars.
(C) Rose-Bengale media for fungi cultivated after 8 days aging.
(D) Albumin media for bacteria and actinomycetes cultivated after 11 days aging.
The addition of coal ash promoted the microbial activity.

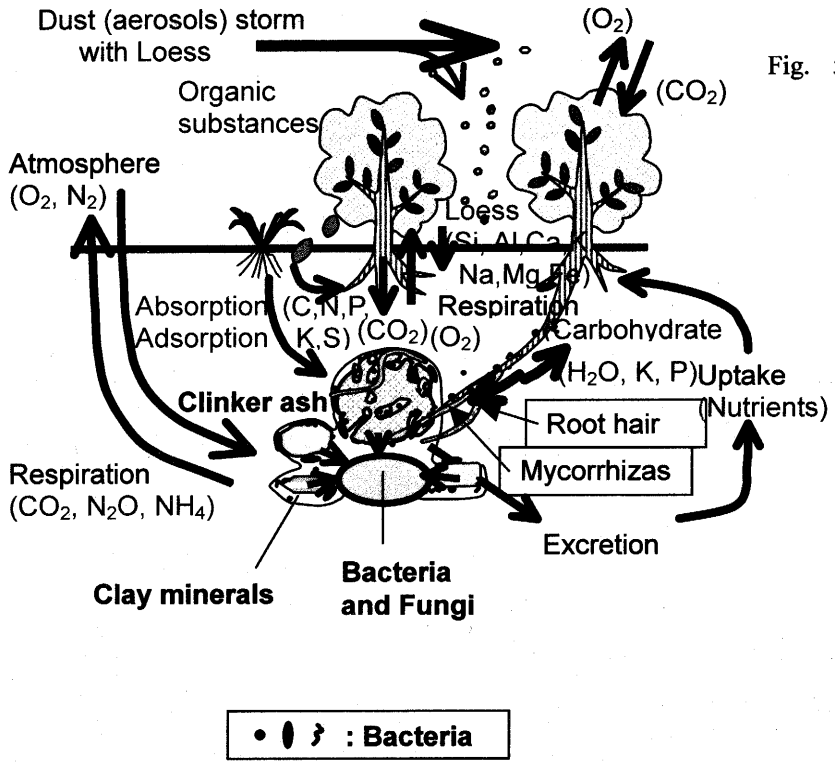

Fig. 5 Schematic models of interaction between coal (clinker) ash and microbes around the plants root. Because the clinker ash multiplies the bacteria and fungi, the supply of nutrients for plant root increases. This processes may develop the mycorrhizas and brisk the rhizosphere activity. Accordingly, the growth of plants is promoted by addition of coal ash. With the growth of plants, the minerals increase by catching from the dust (aerosol) storm. (In case of China, the dust is the Loess.) These minerals offer the nutrients (Si, Al, Ca, K, Na, Mg and Fe) to the soils. Porous space in the soil has high CO_2 with small amount of O_2 due to respiration of microbes and plant roots. The gas-diffusion between the atmosphere and air in soils is necessary for the microbes and plant roots. The clinker ash is capable of ventilation with porous structure.

This application also has possibility to resolve the environmental problems in China, though it is simple and low-cost method. The simple and proper techniques like this one are needed in the developing countries.

Currently, the rate of desertification increases rapidly. The actions of remediation for this problem must be taken immediately. The desertification is not the local problem in specified countries, but the global environmental problem that makes a deep impact widely in various fields like climate change, food supply, water resources and life habitation all. For the further step, it is necessary to test the planting in desertificated field practically.

V. Summary and Conclusions

The natural cultivation experiments and pot planting experiments were performed using desertificated soils of China and coal ashes. The microbes multiplied on and in coal ash, and the plants developed the roots in coal ash more than the plants in pure soils. The addition of coal ash is expected to be very effectual and sustainable way for afforestation in desertificated lands. Recently the desertification is not the local problem in China, but the global environmental problem. In the 21st century, we hope that the desertification would be resolved as early as possible by means of sustainable way.

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